ENDEAVOUR

Volume VII Number 25

JANUARY 1948

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The drawing on the cover is of the barque Endeavour, *which, commanded by Captain James Cook and carrying a number of scientific workers, was sent out by the British Admiralty in* 1768 *to chart the South Pacific Ocean and observe the transit of Venus*

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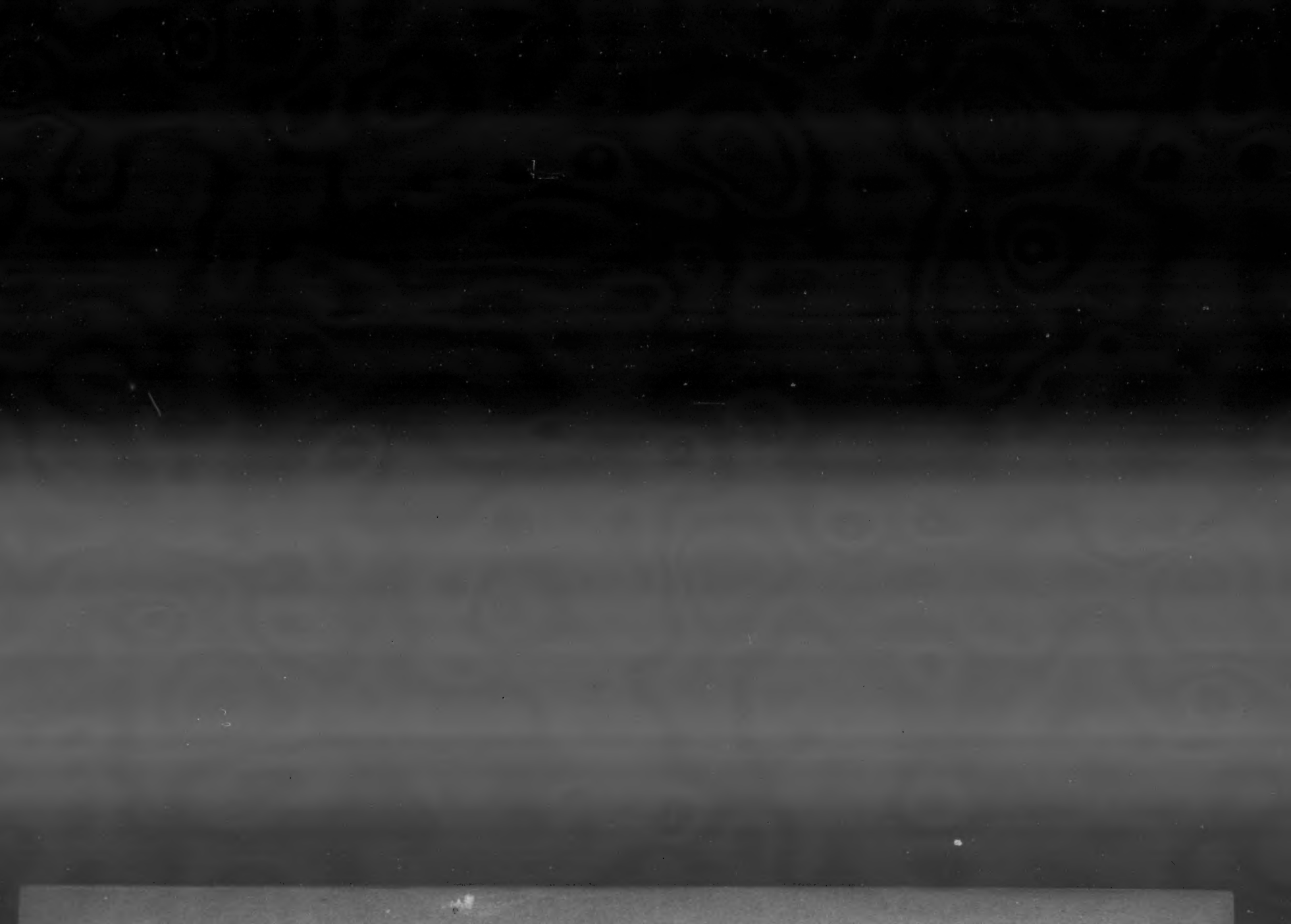

ENDEAVOUR

A quarterly review designed to record the progress of the sciences in the service of mankind

VOLUME VII JANUARY 1948 NUMBER 25

Science in Italy

We are glad to announce that, beginning with this issue, an Italian edition of ENDEAVOUR is to take its place at the side of those already published in English, French, Spanish, and German. The occasion is a happy one, for the traditional friendship of the British and Italian peoples, so tragically interrupted by the recent war, has now been cemented anew and holds auspicious promise of future co-operation. Scientists in particular will welcome the revived communion, for few countries have such a brilliant record of scientific achievement as Italy. We cannot here attempt to pay full tribute to this record, but with the launching of ENDEAVOUR in its Italian dress we may fittingly and pleasurably recall a few at least of the innumerable contributions to science made by the countrymen of Galileo.

The story does not begin with Galileo, for the torch of science had burned in Italy long before the sixteenth century. Two or three hundred years earlier the Venetian and Pisan colonies in Constantinople were assimilating the wisdom of the East and transmitting it to their native land; 'many tongued Sicily' was the epitome of Mediterranean knowledge; and the Emperor Frederick II typified his love for experiment by ringing, in 1230, a pike which was long afterwards caught again and presented to the Elector Palatine. This intellectual activity reached its first peak in the person of Leonardo da Vinci (1452–1519), who combined artistic genius with remarkable acumen as biologist, physicist, and mathematician. He was one of the founders of the modern theory of optics, made noteworthy advances in geometry, worked on capillarity, centres of gravity, and frictional resistance, and in the field of anatomy proved himself 'a modern biologist in the disguise of a mediaeval artist.'

Leonardo also paid some attention to statics, but the science of dynamics had yet to be created. This fundamental step in the progress of natural philosophy was made by Galileo Galilei, who was born of Florentine parents at Pisa on 15th February, 1564. A favourable home atmosphere quickened Galileo's diverse mental aptitudes, and he was well equipped to benefit from the further education he received at a monastery in Vallombrosa and at the University of Pisa. At first he read medicine and philosophy, but he gradually discovered that his true talent lay in mathematics and withdrew from the University without completing his medical course.

Galileo's first important discovery, namely that of the synchronism of the oscillations of a pendulum, was made when he was only 18 or 19 years of age. The discovery was employed by physicians in measuring the rate of the pulse, and went far to make Galileo's name familiar throughout his native land. A few years later, in 1589, he was appointed to the chair of mathematics at Pisa, where he became known as 'the wrangler' on account of his characteristic habit of questioning every assertion—even of so sacrosanct an authority as Aristotle. It was at Pisa that he made his public demonstration of the falsity of the Aristotelian thesis that bodies fall at speeds proportional to their weights—a demonstration which his fellow dons found infamous if not blasphemous, but which in fact may be said to mark the effective birth of modern science.

Conditions at Pisa having become intolerable, Galileo removed to Padua, where he was professor of mathematics from 1592 to 1610. This was the most fruitful period of his life, for during it he not only carried out his great work on dynamics but constructed the first astronomical telescope, with which he observed the satellites of Jupiter and the spots on the sun. He also invented the modern type of microscope and made the first air thermometer. The pitiful story of

his trial by the Inquisition for his support of the Copernican system is too well known to bear repetition, and, though he was forced to make public recantation, the legendary '*Eppur si muove*' must yet have remained his unshakable conviction. Blind and wasted by disease in his declining years, Galileo's last days were to some extent cheered by the society and conversation of his disciple Evangelista Torricelli, who succeeded to one of his professorial chairs and is himself remembered as the inventor of the mercury barometer.

A younger contemporary of Galileo was the mathematician and physicist Giovanni Alfonso Borelli (1608–79), professor at Messina and later at Pisa. Borelli was of only moderate ability at mathematics but found a congenial field for applying his knowledge in the investigation of the movements of animals. His great work on this subject, *De motu animalium*, is one of the classics of physiology, and his treatment of the problems of haemodynamics was scarcely improved upon until the middle of the nineteenth century. Borelli's example inspired an even more able physiologist in the person of Marcello Malpighi (1628–94), who was among the first to direct the microscope to biological problems and thus discovered the true structure of the kidney and the details of the circulation of the blood: 'Harvey showed that the blood did sweep through the tissues, Malpighi showed what the tissues were and how the blood swept through them,' so paving the way for basically important later investigations. In the following century, physiology and natural history were further advanced by the accomplished scientist Lazzaro Spallanzani (1729–99), who worked on the processes of reproduction, respiration, and digestion.

Italian major contributions to chemistry came later than those to astronomy, physics, and biology, but one of them had a profound influence upon the progress of the science. It was made by Amedeo Avogadro (1776–1856), professor of mathematical physics at Turin, and is familiar to all scientists as 'Avogadro's hypothesis.' Avogadro, in short, was the first to differentiate clearly between atoms and molecules and, by assuming that equal volumes of all gases contain equal numbers of molecules (at the same temperature and pressure), to provide chemists with a means of comparing molecular weights. Unfortunately Avogadro's work was long overlooked, and it remained for his fellow-countryman Stanislao Cannizzaro (1826–1910) to bring it into prominence nearly fifty years after its original announcement.

Another essential feature of chemistry, though not of immediate Italian origin, was ultimately based upon Italian discoveries, namely electrochemistry. As is well known, this branch of science was founded by Davy, Berzelius, and Faraday, but its principal tool in early days was the electric battery invented by Alessandro Volta (1745–1827).

Such were some of the achievements of Italian science up to and including the nineteenth century. That the mastery still persists in this twentieth century is abundantly clear—so abundantly, indeed, that far more than the present space would be required to describe it even in outline. One name, of course, stands out above the rest—that of Guglielmo Marconi (1874–1937), whose work on wireless telegraphy and telephony brought him fame and honour in all parts of the world. It cannot be an exaggeration to say that Marconi's researches and inventions have as widely and deeply affected the course of civilization as those of any of the great men of science who preceded or have followed him.

Of the present-day trends of scientific work in Italy this is not the occasion to write fully, but we may mention the fruitful researches in progress there on cosmic rays, electro-acoustics, geophysics, seismology and prospecting, high-frequency technique, nuclear physics, and the development of water power. Scientific research is more highly organized in Italy than in many other countries, a number of specialized institutes working under the *Consiglio Nazionale delle Ricerche*. We hope that the Italian edition of ENDEAVOUR may help in a modest way to further the international co-operation which is the life-blood of science.

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Carotenoid pigments

PAUL KARRER

Although the existence of carotenoid pigments has been known for more than a century it is only comparatively recently that their chemistry has been closely investigated. Since 1928 nearly seventy different pigments of this interesting class have been isolated and characterized. This rapid development is due in large measure to the use of chromatography, a modern method of analysis particularly suitable for resolving mixtures of substances which, like the carotenoids, differ relatively little in their chemical and physical properties.

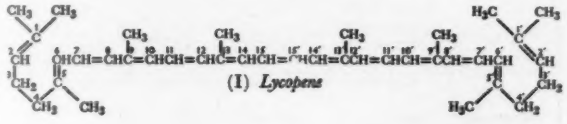
The pigments of the plant and animal kingdoms are of very diverse chemical composition. Many of them, however, can be classified in groups of closely related pigments; the members of such groups usually differ only in the details of their structure. Examples of such natural groups are the yellow flavone and flavonol pigments, the blue and red anthocyanins, the green chlorophylls built up from pyrrole nuclei, red haemins, and bilirubins. Quinone dyestuffs are of the same type. To these large groups of pigments, which impart to living things their pleasing colours, has recently been added the carotenoid group.

The existence of carotenoids has long been known. Berzelius studied xanthophyll, a mixture of carotenoids. In 1831 Wackenroder isolated carotene for the first time from carrots. For a long time, however, such observations were sporadic. Up to 1928 seven pigments in all had been discovered which appeared to be related to carotene, although they were not definitely proved to be so. Modern carotenoid research began only after 1928. By applying up-to-date methods of investigation it was possible quickly to build up this group of natural pigments. Today it comprises some 65–70 substances.

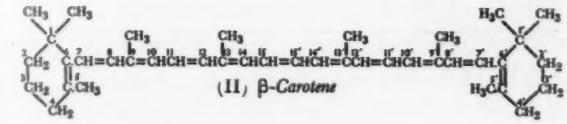
Carotenoids are present in most plants (with the exception of certain fungi) and probably in all animals, but their concentration is almost always very low. The content of carotenoid pigments (the sum of carotenes and xanthophyll) in green leaves is approximately 0·07–0·20 per cent. (based upon the dry weight of the leaves), and in carrots 0·02–0·13 per cent. In exceptional cases, however, higher pigment concentrations are found. Thus in *Trentepohlia aurea* (common red byssus) about 1 per cent. of the dry weight consists of carotene, and the anthers of many types of lily contain surprisingly large quantities of xanthophyll epoxide and antheraxanthin (zeaxanthin epoxide).

All natural carotenoids may be regarded as derivatives of the tomato pigment lycopene. By closing the ring of the lycopene molecule on one or on both sides, the three carotenes β-, α-, and γ-carotene are produced (formulae II, III, IV).

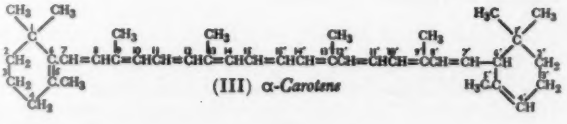
These structural formulae were established beyond doubt by means of various decomposition and transformation reactions. Lycopene and its closed-ring relations, β-, α-, and γ-carotene, contain forty carbon atoms and may be regarded as compounded of eight isoprene residues. One of their characteristic features is the large number of conjugated double bonds forming their chromophore groups. The carotenoids are thus a subdivision of the polyene pigments.



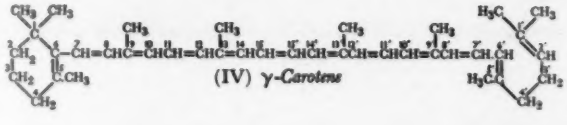
(I) *Lycopene*



(II) β-*Carotene*



(III) α-*Carotene*



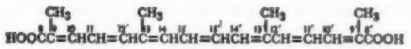
(IV) γ-*Carotene*

The other carotenoids of which the structures have been established can without exception be regarded as derivatives of the four hydrocarbons formulated above. They are derived from them by the introduction of hydroxyl, carbonyl, epoxide, and methoxyl groups, or by partial hydrogenation or oxidation.

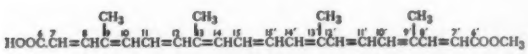
A few of the more important derivatives of this kind are summarized in the following table:

Derivatives of:		
Lycopene	Lycoxanthin	(3-oxylycopene)
	Lycophyll	(3,3′-dioxylycopene)
β-Carotene	Cryptoxanthin	(3-oxy-β-carotene)
	Zeaxanthin	(3,3′-dioxy-β-carotene)
	Antheraxanthin	(zeaxanthin-5,6-epoxide)
	Violaxanthin	(zeaxanthin-5,6-5′,6′-diepoxide)
	Citroxanthin	(furanoid monoxide of β-carotene)
	Auroxanthin	(furanoid zeaxanthin dioxide)
	Aphanin	(3-keto-β-carotene) (?)
	Rhodoxanthin	(3,3′-diketo-β-carotene)
	Astacin	(3,4,3′,4′-tetraketo-β-carotene)
	Astaxanthin	(3,3′-dioxy-4,4′-diketo-β-carotene)
	Capsanthin	
	Capsorubin	
α-Carotene	Xanthophyll	(3,3′-dioxy-α-carotene)
	Xanthophyll-5,6-epoxide	
	α-Carotene-5,6-epoxide	
	Flavoxanthin	(furanoid xanthophyll epoxide)
	Chrysanthemaxanthin	(furanoid xanthophyll oxide)
γ-Carotene	Rubixanthin	(3-oxy-γ-carotene)
	Rubichrome	(furanoid rubixanthin oxide)
	Eschscholtzxanthin	(dioxy-γ-carotene) (?)

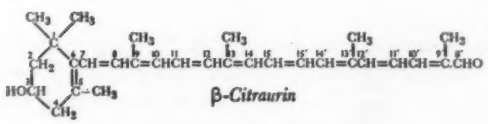
The following compounds are examples of natural pigments which may be regarded as oxidation products of various carotenoids containing forty carbon atoms:



Crocetin



Bixin



β-Citraurin

From a comparison of the last three structural formulae with those of lycopene and of β-, α-, and γ-carotene, it is easy to see which carbon atoms of the hydrocarbons have been preserved in the crocetin, bixin, and β-citraurin, and those which have been removed by oxidation.

It is often difficult to isolate and purify the carotenoids. It is primarily to chromatography that we owe our present ability to separate quantitatively such closely related substances as α- and β-carotene, which differ only in the position of one double bond, or to extract all the γ-carotene from a mixture of α-, β-, and γ-carotene in which the last is present to the extent of only 1 or 0·1 per cent. The process of separation by chromatography was invented some considerable time ago (1906) by the botanist Tswett. It consists in allowing a solution of the mixture of substances which it is desired to separate to run through an adsorption column, which is afterwards washed with the solvent. This subsequent washing—development of the chromatogram—continuously elutes the adsorbed substances and precipitates them again lower down on the column of adsorbent. As the elution of the more strongly adsorbed components takes place more slowly than the elution of the substances which are less strongly adsorbed, this process of development effects a sharp separation of the individual constituents of the mixture.

Tswett himself used this process for the separation of carotenoids, although only for qualitative analysis. It is only recently that chromatography has been used for the purification and quantitative separation of carotenoids on a preparative scale. There are numerous mixtures of carotenoid pigments which, but for this efficient method, we should not today be able to separate.

The tenacity with which the carotenoids adhere to the adsorption column, which may consist of aluminium oxide, calcium hydroxide, calcium carbonate, or zinc carbonate, depends first and foremost on the functional groups present in the pigment molecules. Carboxyl and hydroxyl groups raise the power of adsorption very strongly, and in proportion to their number. Thus carotenoid carboxylic acids and di- and poly-oxycarotenoids will be found in the upper part of a Tswett adsorption column; lower down will come mono-oxy compounds, ketones, aldehydes, and so on. Finally, at the bottom, come the hydrocarbons.

Figure 1 shows the appearance of a mixture of

2. Dihydro-β-Carotene, *a carotenoid with 10 conjugated double bonds.*
3. β-Carotene, *a carotenoid with* 11 *conjugated double bonds.*
4. Lycopene, *a carotenoid with* 11 *conjugated and* 2 *isolated double bonds (equivalent to* 13 *conjugated double bonds).*

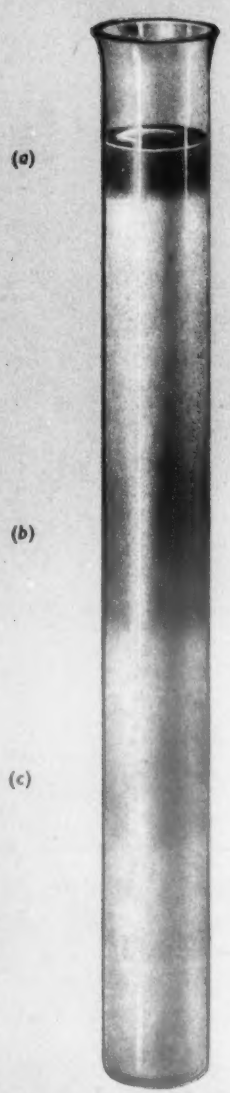


FIGURE 1 – *Chromatographic separation of lycopene* (*a*), β-*carotene* (*b*), *and* α-*carotene* (*c*).

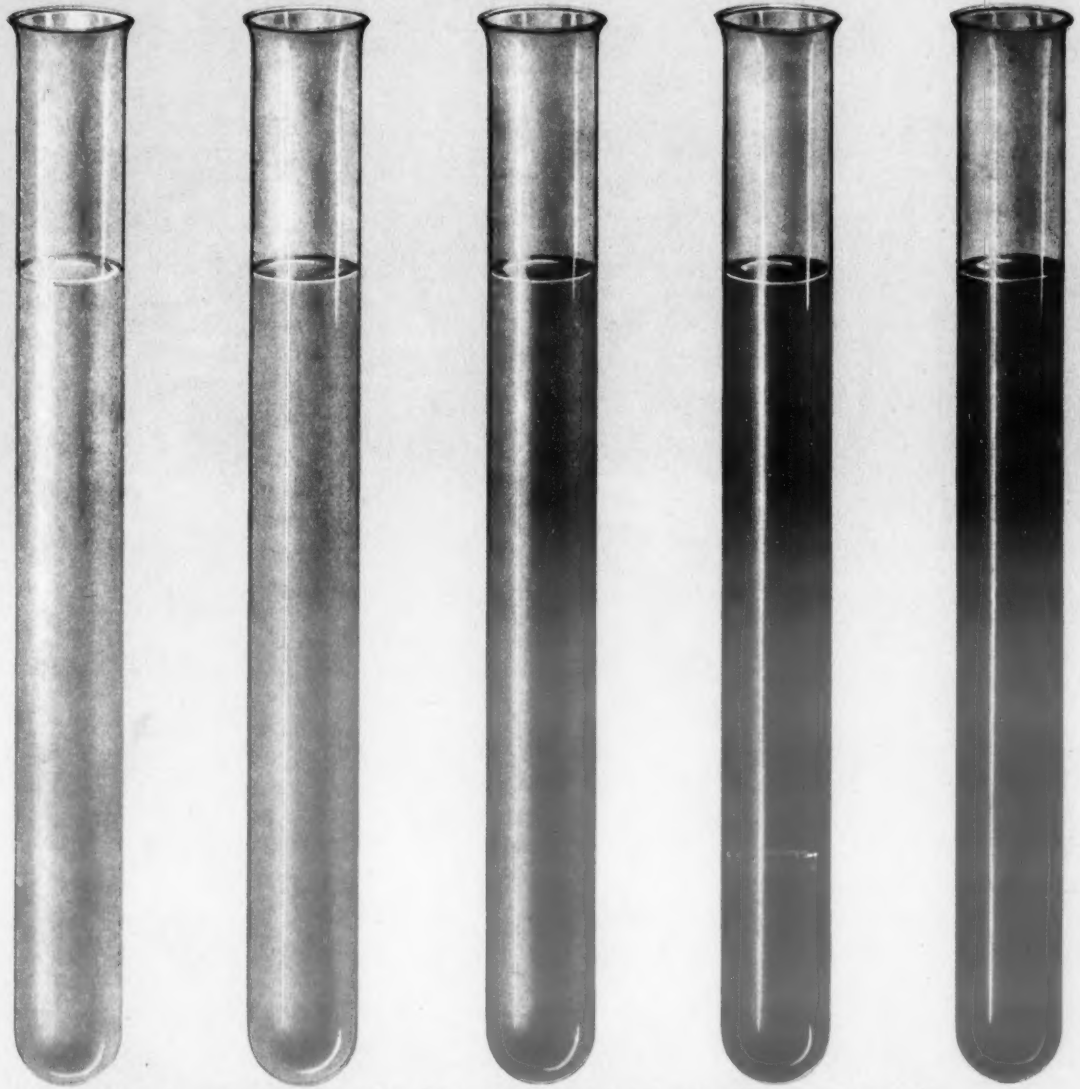


FIGURE 2 (*reading from left to right*) – *Solutions of various carotenoids in carbon disulphide.*

1. Auroxanthin, *a carotenoid with* 7 *conjugated and* 2 *isolated double bonds* (*equivalent to* 8 *conjugated double bonds*).
2. Dihydro-β-carotene, *a carotenoid with* 10 *conjugated double bonds.*
3. β-Carotene, *a carotenoid with* 11 *conjugated double bonds.*
4. Lycopene, *a carotenoid with* 11 *conjugated and* 2 *isolated double bonds* (*equivalent to* 13 *conjugated double bonds*).

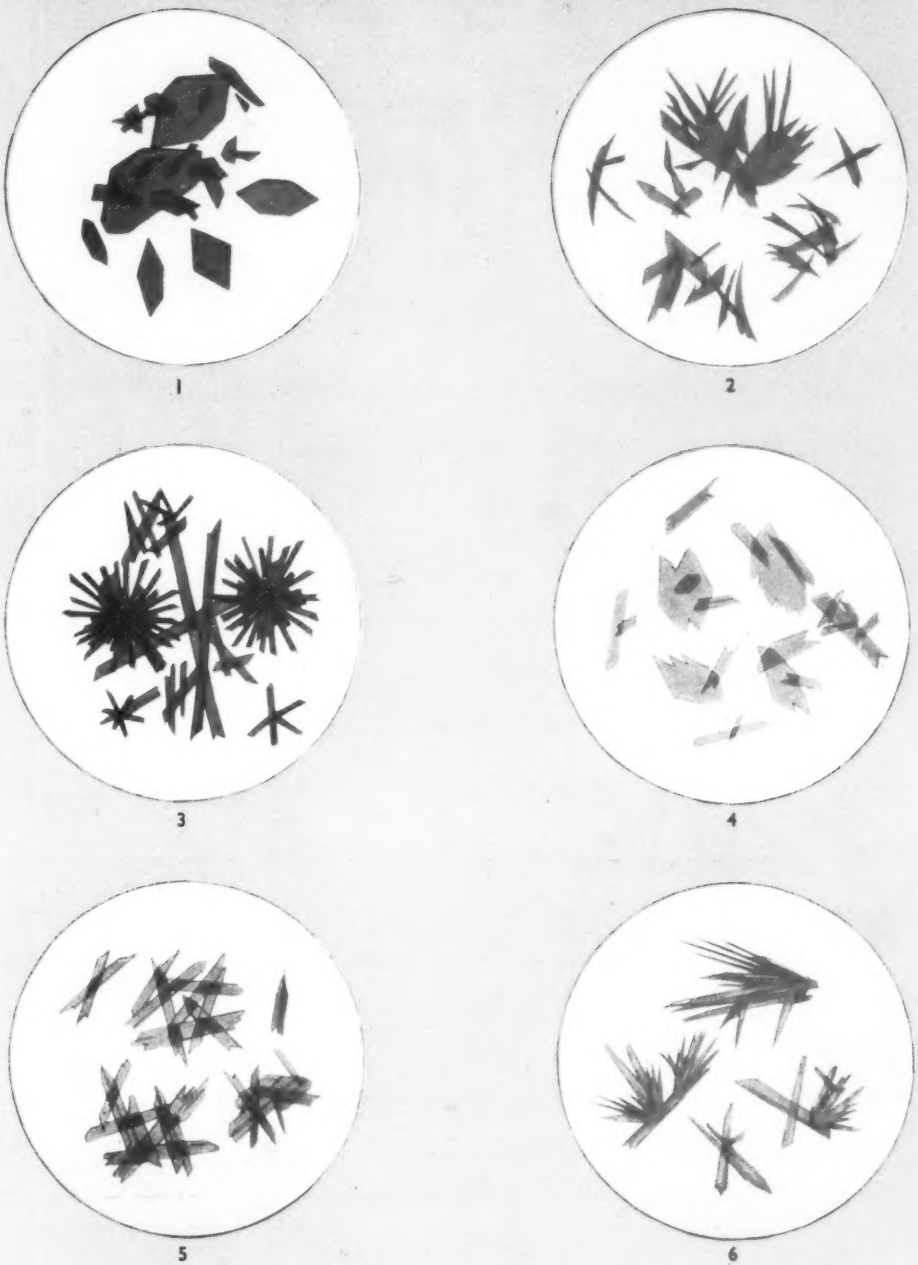


FIGURE 3

1. β-*Carotene crystallized from petroleum ether.*
2. α-*Carotene crystallized from petroleum ether.*
3. *Lycopene crystallized from petroleum ether.*
4. *Xanthophyll crystallized from a mixture of methyl alcohol and ether.*
5. *Zeaxanthin crystallized from a mixture of methyl alcohol and ether.*
6. *Violaxanthin crystallized from a mixture of methyl alcohol and ether.*

β-carotene, lycopene, and α-carotene after chromatographic analysis.

The absorption spectra of the carotenoids provide a valuable means of identifying them and of checking their purity. Almost all carotenoid pigments have three sharply defined maxima in the visible part of their spectrum. The position of these maxima is determined mainly by the chromophore present, i.e. by the number of double bonds in the respective pigment. Each new carbon double bond entering into the conjugated system of double bonds displaces the absorption maxima towards longer wavelengths by approximately the same amount, namely 200–220 A.

The absorption conditions in the ultra-violet range are somewhat less regular and more dependent on the other constitutional characteristics of the pigment. Figure 4 shows absorption curves for a few of the more important carotenoid pigments.

Other chromophores, such as =C=O and —COOH groups, cause a deepening of the colour, particularly when they are associated with the system of conjugated double bonds. The effect of a carbonyl group under these circumstances is a displacement of the absorption maxima in the visible spectral range by about 400 A. Much more frequently, however, the conjugated system of carbon double bonds itself is almost entirely responsible for the colour. Carotenoids are now known in which the number of double bonds varies from 6 to 15. The colours of their solutions range correspondingly from yellow to violet, as shown in figure 2.

All carotenoid pigments crystallize very readily. In reflected light the crystals appear yellow, orange, or red; some (astacin, for example) are almost black, depending upon the composition of the substance and the development of the crystals. By transmitted light, all crystals of carotenoids appear yellow, orange, or red. The crystals are often dichroic. Figure 3 gives an indication of their shapes and colours.

The interest of modern research on carotenoids is due in part to the physiological importance of some individual members of the group. Carotenoids are formed mainly in plants, and it is doubtful whether animal organisms are capable of bringing about more than slight changes in the molecules of these pigments. No facts are at present known which would justify the assumption that a carotenoid found in the organism of an animal might have been synthesized there from simpler substances. In spite of the fact that the carotenoids are thus primarily vegetable pigments, very little is known regarding their significance in the

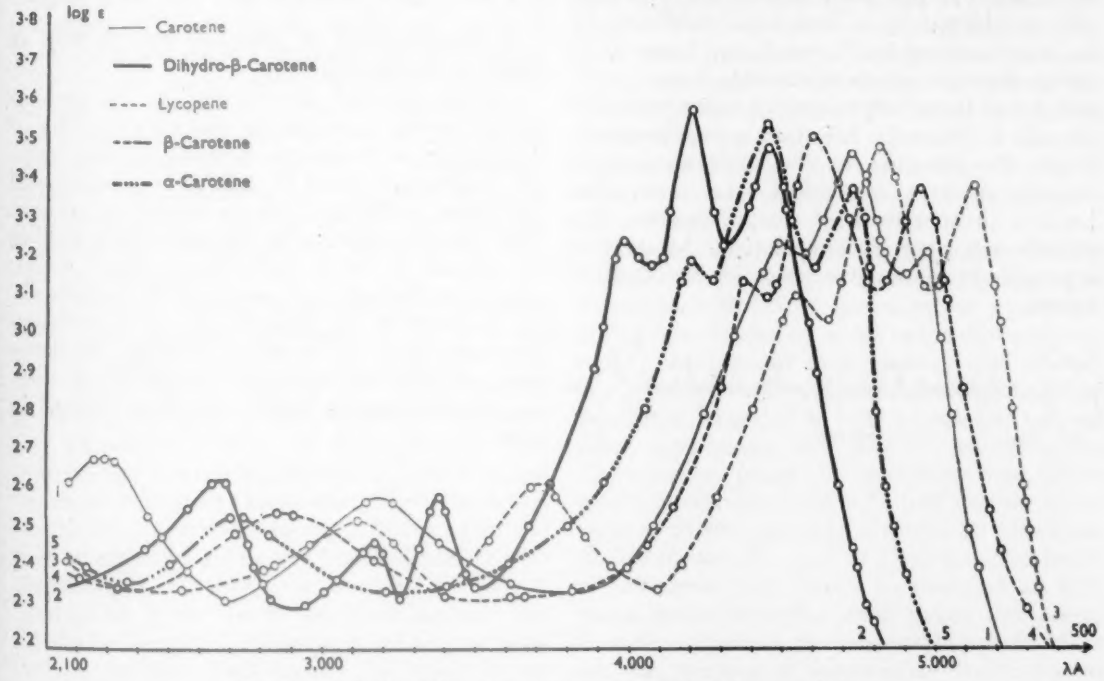


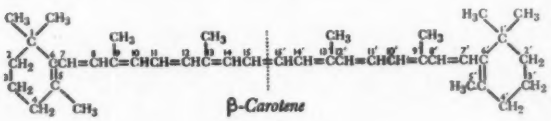
FIGURE 4 – *Absorption spectra of some carotenoids in hexane solution.*

life of plants. β-Carotene (and to a lesser extent α- and γ-carotene as well) and xanthophyll are present in every green leaf in quantities roughly proportional to the chlorophyll content of the leaf. The question whether these two yellow pigments take part in the assimilation process or in the respiration of the plant has often been discussed, but no satisfactory answer has yet been found.

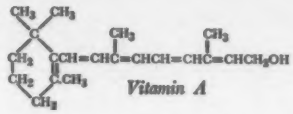
Kuhn and Moevus assert that crocin (crocetin digentiobiose ester) and *trans*- and *cis*-crocetin play a part in the reproduction of the unicellular alga *Chlamydomonas eugametos f. simplex*. Crocin can bring about flagellum-formation in the gametes of these plants, and mixtures of *trans*- and *cis*-crocetin can then transform the mobile gametes into male or female gametes. The ratio of *cis*- to *trans*-crocetin determines whether male or female gametes are formed. These experiments require further confirmation.

The widespread diffusion of carotenoid epoxides throughout the vegetable kingdom and the ease with which they give up their oxygen has led to the surmise that in certain vegetable organs these substances may act as oxygen carriers, but it has not yet been possible to confirm this hypothesis.

We have more exact information regarding the importance of some carotenoids to animal organisms. It has been proved that carotene acts as vitamin A, a fact first established by H. Steenbock and by H. von Euler. Later it was shown that this action of carotene is due to the fact that in animal organisms it is transformed into vitamin A (Moore). It is thus a pro-vitamin A. When the structure of the carotenes and of vitamin A were established, the connections between them were more comprehensible. The transformation of β-carotene into vitamin A is possible by splitting the molecules into identical halves:



β-*Carotene*



Vitamin A

β-Carotene is not the only pigment of this group of compounds which possesses the characteristics of a pro-vitamin A. The same physiological effect is exercised by all those pigments which contain in their molecules at least one of the groups comprising half the β-carotene molecule. These natural pro-vitamins A, which are present in plants, are the following:

α-carotene
β-carotene
γ-carotene
α-carotene-5,6-epoxide
citroxanthin (furanoid monoxide of β-carotene)
cryptoxanthin (3-oxy-β-carotene)
myxoxanthin
aphanin (3-keto-β-carotene) (?)
echinenone
torularhodin.

A large number of synthetic pro-vitamins A have been prepared.

Carotenoids are also present in the eyes of human beings and animals, and appear to be of importance in the process of vision. Visual purple, or rhodopsin, is today thought to be a compound of a type of albumin with the carotenoid retinin. The latter is probably the aldehyde corresponding to vitamin A. When light acts on visual purple, retinin is liberated and transformed into vitamin A. In the dark, the visual purple is reconstituted from vitamin A and retinin (G. Wald). We know even less, however, about the part played by other carotenoid pigments which have been detected in eyes.

The Royal Observatory, Greenwich

SIR HAROLD SPENCER JONES

The Greenwich meridian was adopted, at an international conference held in 1884, as the prime meridian of the world. At the same conference a system of time zones based upon Greenwich Mean Time was recommended. These decisions were a recognition of the great services the Observatory had rendered to navigation. The Observatory has also carried out fundamental astronomical research in many other directions. Its current removal to Herstmonceux Castle, in Sussex, promises an opportunity for enhancing an already great reputation.

The Royal Observatory, the oldest scientific institution in Great Britain, was founded by King Charles II in 1675 for the practical purpose of assisting navigation. At that time there was no method of finding the longitude at sea. The suggestion had been made that the longitude could be found by measuring the distances of the Moon from adjacent bright stars. When this was brought to the notice of the King, he referred it to a committee of scientific men for a report. The report was prepared by the Rev. John Flamsteed (1646–1719), who had acquired a considerable reputation as a practical astronomer. It pointed out that the positions of the Moon given by the best tables differed as much as one-third of a degree from the true positions, while the star catalogue of Tycho Brahe, which was nearly a hundred years old, was erroneous and incomplete. The method was in theory correct but could not be applied in practice 'till both the places of the fixed stars were rectified, and new tables of the Moon's motion made, that might represent her place in the heavens to some tolerable degree of exactness; for which a large stock of very accurate observations, continued for some years, was altogether requisite.'

Charles II decided to found an observatory where the required observations could be made, and to appoint Flamsteed as the astronomer to do the work. He provided a site on the highest ground in his park at Greenwich and appointed Sir Christopher Wren as the architect. The observatory was erected at a cost of £520, defrayed by the sale of spoilt gunpowder. There Flamsteed began his observations in 1675. His position was not an easy one, for he was provided neither with instruments nor with assistants. His friend and patron, Sir Jonas Moore, presented him with two clocks by Tompion, and a large iron sextant, with which, working single-handed, he made 20,000 observations in thirteen years. But these observations gave only relative positions. It was not until 1689 that Flamsteed was able to install a large mural arc and to derive absolute positions. In all, he spent upwards of £2,000 above his meagre salary of £100 a year in furnishing instruments and in hiring assistants and computers.

Flamsteed's observations were planned with a careful attention to accuracy. They are, in fact, the earliest from which the phenomenon of aberration is clearly deducible. He introduced new methods into practical astronomy, many of which are in use today, and an immense mass of computations was carried out in a systematic and orderly manner to correct the theories and to improve the tables of the Sun, Moon, and planets, and to elucidate intricate points in practice and theory. The collected observations, including his great star catalogue of nearly three thousand stars, were printed at his own expense as the *Historia Coelestis Britannica*. He died in 1719, when much of the printing still remained to be done. This work was the first great contribution to science given by the Greenwich Observatory to the world.

Edmond Halley (1656–1742), the Savilian Professor of Geometry at Oxford, was appointed Astronomer Royal in succession to Flamsteed. Halley was a man of great originality and versatility, eminent in many branches of science. His authority in astronomical matters was so great that, although he was 63 years of age, no other appointment was possible. He found the Observatory devoid of equipment, for Flamsteed's instruments, which he had paid for out of his own pocket, had been removed by his widow. Halley obtained a grant of £500 from the Board of Ordnance, with which he procured an 8 ft. mural quadrant and a small transit instrument. In order to improve the current tables of the Moon for the purpose of determining longitudes, he planned to observe the Moon through a complete

revolution of its nodes—nearly nineteen years—a task which, in spite of his advanced age, he completed. His observations and his general astronomical tables were published in 1749.

Halley was succeeded by the Rev. James Bradley (1693–1762), the Savilian Professor of Astronomy at Oxford, a great practical astronomer and a skilful observer. Bradley had already acquired fame by his discovery in 1728 of the phenomenon of the aberration of light, from observations with a 12 ft. zenith sector of the zenithal star, Gamma Draconis. He continued his observations of this star through a complete revolution of the Moon's nodes, and in 1748 announced the discovery of the nutation of the Earth's axis, the cause of which he correctly explained.

Bradley added two mural quadrants and a transit instrument to the equipment, the cost being defrayed out of a grant of £1,000 provided by the Admiralty from the sale of old naval stores. His zenith sector was also bought for the Observatory out of the grant. With these instruments some 60,000 observations of the fixed stars were made between 1750 and 1762, with the aid of one assistant. Bradley determined the laws of atmospheric refraction and was the first to introduce corrections for the temperature of the air and for the height of the barometer. His observations surpassed in accuracy any made up to his time: they are the earliest which are accurate enough to be of use to the astronomers of today.

The Rev. Nevil Maskelyne (1732–1811) was appointed Astronomer Royal in 1765, on the death, after a brief tenure of office, of Bradley's successor, the Rev. Nathaniel Bliss. Maskelyne took a great interest in practical navigation. He convinced himself by trials at sea that the method of lunar distances had at length become a practicable one, and that, with the aid of the new tables of the Moon prepared by Tobias Mayer and published at the expense of the Board of Longitude, it was capable of determining the longitude with satisfactory accuracy. Maskelyne provided a most valuable aid to navigation in the preparation of the *Nautical Almanac*, first published for the year 1767. He continued to produce it annually for forty-four years until his death. The invention of the marine chronometer by John Harrison, a Yorkshire carpenter (1693–1776), had provided a practical solution of the longitude problem, but astronomical observations were still required as a check on the error and rate of the chronometer.

Various improvements to the instruments and in the methods of observation were made by Maskelyne. He gave special attention to observations of the Moon to obtain data for the correction of Mayer's Lunar Tables. The Sun, planets, and thirty-six fundamental stars were regularly observed. His determination of the proper motions of these stars provided the data used by William Herschel to derive the motion of the Sun in space. In 1774 Maskelyne made the first measurement of the density and mass of the earth, from observations of the deflection of the plumb-line to the north and south of the mountain of Schiehallion. A mean density of 4·7 times that of water was obtained, a value which agrees with the true value within the uncertainty of the estimate of the mass of the mountain.

The progressive improvement in the accuracy of observation was continued under John Pond (1767–1836), who succeeded Maskelyne in 1811. The construction of a new mural circle, ordered by Maskelyne, was completed in 1812, and a 5 in. transit instrument replaced Bradley's small one in 1816. Pond introduced the use of the mercury horizon for determining instrumental flexure and the position of the nadir point. His catalogue of the positions of 1,112 stars, completed in 1833, was the most valuable contribution of the period to positional astronomy.

In 1818 the control of the Observatory passed from the Board of Ordnance to the Board of Admiralty, and in 1821 the charge of chronometers used in the Royal Navy was transferred to the Observatory. The first public time-signal was inaugurated in 1833; it consisted in the dropping of a time ball at 1 o'clock p.m. daily from the top of a mast erected on the Wren building. Ships in the adjacent reaches of the river and in the docks were thereby enabled to regulate their chronometers.

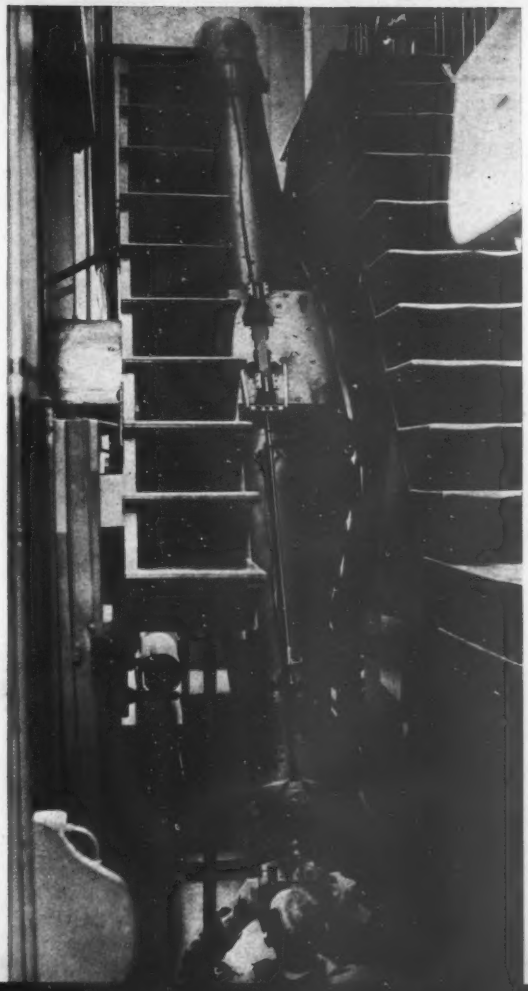
During the later years of his tenure of office Pond's health was failing, his First Assistant was inefficient, and the routine work of testing chronometers occupied an unduly large portion of the time of the small staff. The Observatory consequently fell into a state of disrepute. When Pond resigned in 1835, George Biddell Airy (1801–92) was called in to reorganize the Observatory. Airy had been elected Lucasian Professor of Mathematics at Cambridge in 1826, and Plumian Professor of Astronomy, with the direction of the new Cambridge Observatory, in 1828. A man of rigid routine, a strict disciplinarian, with wide interests and of exceptional ability, he was the ideal man for the task. During his long tenure

FIGURE 1 – *Interior of the Octagon Room in Flamsteed's time, showing the two Tompion clocks* (A *and* B) *and the quadrant with which most of the observations from* 1675 *to* 1689 *were made.*

FIGURE 2 – *The Rev. John Flamsteed, Astronomer Royal,* 1675–1719.

FIGURE 3 – *Sir George Airy, Astronomer Royal,* 1835–81.

FIGURE 4 (*above*) – *Herstmonceux Castle, the future home of the Royal Observatory.*



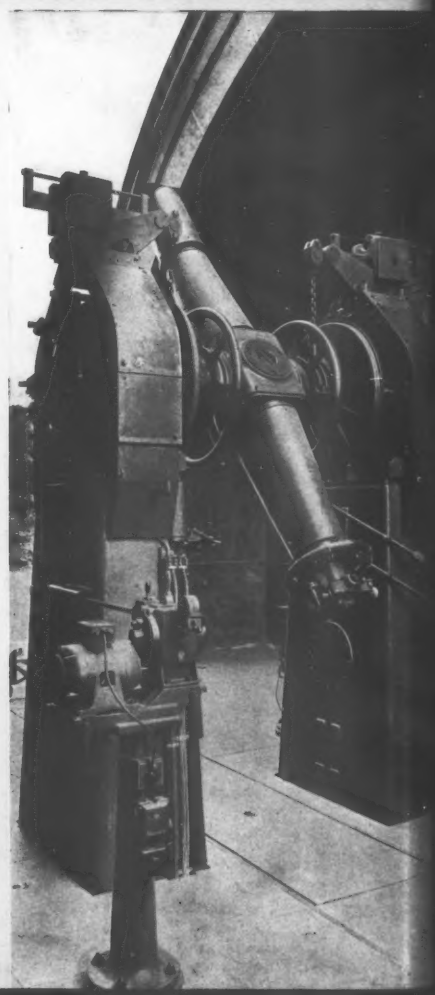


FIGURE 5 (*right*) – *The Thompson 26 in. photographic refractor and the Yapp 36 in. reflector with slitless spectroscope attached.*

of office the Observatory acquired a great reputation: he became the most commanding figure in the astronomy of his time, and was called in to advise the Government on a great variety of matters. He was, for instance, chairman of the Commission responsible for the restoration of standards of length and weight after their destruction in the great fire at the Houses of Parliament. On the development of iron ships he devised methods, which are still in use, for the correction of ship's compasses. He also prepared the report on the gauge to be adopted as standard by railways.

The meridian observations, which formed the traditional work of the Observatory, were continued systematically and with great energy, special attention being paid to the planets, the observation of which had been much neglected by Pond. An altazimuth instrument was installed in 1847 to enable observations of the Moon to be obtained in parts of her orbit where she could not be observed on the meridian. A large transit circle, to do the work previously done by the transit instrument and the mural circle, was designed by Airy and brought into use in 1851. This famous instrument, which was later to define the prime meridian of longitude, has continued in use to the present time: more than 650,000 observations of the Sun, Moon, planets, and stars have been made with it. A natural development of the meridian work, made possible by the introduction of telephonic communication, was the distribution of time to the Post Office, to the railways, and to the Admiralty dockyards. Greenwich Mean Time was not adopted as the legal time of Great Britain until 1880. Before that date local mean time was often used, but the growth of railway communications had resulted in the general use of G.M.T., which was popularly known as Railway Time.

Airy soon saw the need for the extension in new directions of the work of the Observatory, which had hitherto been confined to positional astronomy. A magnetic and meteorological department was established in 1840. At first, magnetic observations were usually made at intervals throughout the day and night, but in 1848 continuous photographic registration was introduced. The observations were continued at Greenwich until 1923, when the electrification of the local railways necessitated the removal of the instruments to a new site, a separate magnetic observatory being established at Abinger in Surrey. The Royal Observatory has the longest continuous series of magnetic observations in the world.

The association between terrestrial magnetic disturbances and sunspots suggested the need for these related phenomena to be studied together. Accordingly, in 1873 a photoheliograph was installed for the regular daily photography of the Sun. Similar observations were also initiated at the Cape Observatory (South Africa), the photographs being sent to Greenwich. The combined series provides a practically continuous record of the Sun's surface, which has proved invaluable in a variety of investigations.

Two equatorial refractors were added to the equipment; the Mertz 12¾ in., added in 1858, was a large instrument at that time. Observations of comets, double stars, and of planetary markings were made. With the birth of astrophysics, a spectroscope was added in 1874 for visual observations.

The new developments in the work, and the great activity under Airy's regime, had involved a corresponding increase in staff. In the first 150 years of its existence the work of the Observatory had been largely the personal work of the Astronomer Royal. Now, however, it was on the way to becoming a large institution, with a variety of programmes of work in which the whole staff co-operated. It is possible to refer only to some of the

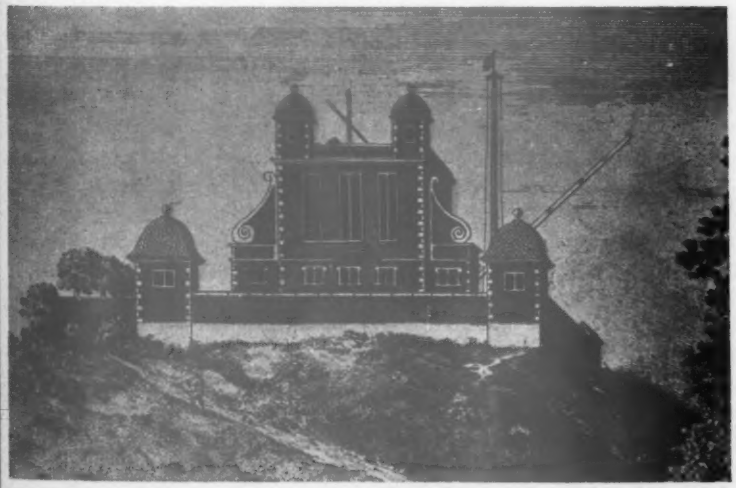


FIGURE 6 – *View of the north aspect of the observatory in Flamsteed's time.*

principal developments since 1881, under the administration of Sir William Christie (Astronomer Royal 1881–1910), Sir Frank Dyson (Astronomer Royal 1910–33), and the writer.

The application of photography to astronomy has led to great and rapid developments. One of the first projects to which photography was applied was the *Carte du Ciel*—a photographic chart and catalogue of the whole sky, in which a number of observatories co-operated, using similar astrographic telescopes of 13 in. aperture. Greenwich assumed responsibility for the cap of 25° radius round the north celestial pole. This region of the sky has become peculiarly a Greenwich region, many programmes of observation having been concentrated on providing additional information about the stars in it. The region was completely rephotographed after about twenty-five years in order to determine the proper motions of the stars. The distances of many of the stars have been measured with the 26 in. refractor, presented, together with a 30 in. reflector, by Sir Henry Thompson in 1894.

A 28 in. visual refractor was added in 1894, and has been used mainly for double star observations. In 1931 Mr W. J. Yapp presented a 36 in. reflector, together with a slitless spectrograph and a slit spectrograph with one-prism and three-prism dispersions. These have been used for the measurement of the colour temperatures of stars, and for general spectrographic investigations.

In 1884 the State Department of the United States convened a conference in Washington to obtain international agreement on the choice of a prime meridian, and the establishment of a zone time-system based on that meridian. The Greenwich Observatory had been so long and so closely concerned with the needs of navigation that no alternative to the meridian of Greenwich was seriously considered. The meridian through the centre of the Airy transit instrument was adopted as the prime meridian, and a system of time zones based on Greenwich Mean Time was recommended and is now in almost universal use.

Meridian observations have continued to be an important part of the work of the Observatory. To meet the requirements for higher precision, a new reversible transit circle was installed in 1936. A wider dissemination of accurate time was made possible by radio. The British Broadcasting Corporation's 'six pips' time signals were inaugurated in 1924. Special rhythmic time signals for navigational use have been sent out twice daily from the Rugby wireless station since 1927. These signals, of world-wide range, enable the navigator to check his chronometers, and have made the old method of lunar distances obsolete. The Post Office 'speaking clock,' installed in 1936 and controlled by hourly signals from the Observatory, has made Greenwich time available by telephone everywhere in Great Britain. At the same time the precision of the time service has been greatly improved to meet practical requirements. The Observatory now bases its time entirely on quartz crystal clocks, eighteen of which have been installed. A 10 in. photographic zenith tube, of special design, is now under construction and will greatly increase the accuracy of time determination.

Expeditions have been sent from time to time to various parts of the world to observe total eclipses of the Sun. Mention may be made of the expedition to Brazil for the eclipse of 29th May, 1919, which provided the first confirmation of Einstein's prediction of the bending of rays of light passing near the Sun.

Greenwich was a village in the country when the Observatory was established in 1675. As a result of the growth of London, particularly during the last few decades, the Observatory is now surrounded by closely built-up areas, with many industrial plants in its vicinity. The smoky atmosphere, and the bright sky at night from the glare of London, have caused a progressive deterioration in the conditions for astronomical observations. The installation of larger and more powerful telescopes at Greenwich could not be justified. In spite of the ties of long tradition, the removal of the Observatory from Greenwich had become necessary if it were to continue to make important contributions to the advancement of astronomy. Proposals were submitted to the Admiralty, and as a result, after a large number of possible sites had been investigated, Herstmonceux Castle in Sussex (built in 1440), together with some 370 acres of surrounding land, has been acquired. The first stages of the removal of the Observatory to Herstmonceux are now in progress. The Government has agreed to provide a large reflector of 100 in. aperture, the use of which is to be shared between the Royal Greenwich Observatory (by which name the Observatory will in future be known) and the other observatories of Great Britain. This powerful new instrument will in due course be erected at Herstmonceux. After 272 years at Greenwich, a new era is now opening in the long history of the Observatory, rich with opportunity and promise for the future.

British coinage and coinage alloys

W. A. C. NEWMAN

The manufacture of coins presents metallurgical problems of great interest, because for historical and economic reasons it is frequently necessary to use alloys which differ considerably from those which would be chosen on the ground of suitability. The assaying of coins also presents difficulties, as some of the alloys used show the phenomenon of segregation, which results in variation in the composition of the alloy in different parts of the casting.

The history of coinage is long and intricate, but the underlying principles are comparatively simple. One of the first methods of exchange was by bartering, but fraud on the one hand, and inconvenience on the other, tended to bring it into disrepute. It should be borne in mind, however, that bartering is not unknown between both nations and individuals at the present time, and that the actual passage of money is rarely necessary in carrying out large international transactions.

Originally, things that had nothing in common by which their value could be assessed proved difficult to exchange, and the accumulation of unwanted goods by anyone fortunate enough to have much of which to dispose was a source of inconvenience and embarrassment. The transition, therefore, to a system in which values were expressed in quantities of some common article—such as shells or notched sticks—was naturally easy.

Such primitive currencies simplified many of the exchange problems, as they made it possible to decide upon and to maintain constant values for commercial goods. But the fragility of objects such as shells quickly led to a search for more permanent materials for currency, so that assets should not—in a very real sense—be 'wasting' ones. Flints, hard rocks, and native metals were tried in turn, but there was always a danger of serious inflation when these commonly occurring materials were used. With the discovery of electrum—an alloy of gold and silver—and of deposits of other durable metals such as gold, silver, and copper (the latter often mixed with baser metals) the age of metallic currency may be said to have started.

There still remained the necessity of indicating the value of the crude and irregular lumps of metal originally used. It became customary to fashion the lumps into regular shapes and weights, such as disks or squares, and to have not only small numerical signs upon them but also designs which could not easily be copied.

There followed the gradual evolution of the present system, in which the weights and compositions of coins are subject to legal control and the obverse and reverse designs are carefully chosen to indicate value and country of origin. It has been said with truth that since the thirteenth century the designs of the coinage of civilized countries have always fairly represented the artistic culture of the periods in which the coins were struck.

In ancient Egypt, and later in the Roman Empire, copper was the standard of value. The Roman pound weight of copper was the *as*, and the Treasury was called the *Aerarium*, or copper store. By the middle of the third century B.C. silver also had become a medium of exchange. The silver unit was the *sestertius*, and later the *denarius*, equivalent to 10 sesterces. The Roman term *denarius* survives in abbreviated form in the British abbreviation 1d. for one penny. Expansion of trade and increase in wealth rendered the silver coins inadequate, and gold, in the form of ingots, became the medium for larger transactions, copper and silver becoming merely token coinages.

These three principal metals were initially used in their natural state or in a crudely refined condition. They derived part of their property of durability from the presence of impurities. Today alloys are preferred to pure metals for the same reason, nickel alone being used unalloyed for coinage purposes. Pure zinc and aluminium have, however, also been tried, despite their inherent disadvantages.

It was not until the thirteenth century that there was a uniform gold coinage in Britain, although foreign gold pieces had previously circulated as gold bullion. The famous gold stater

of Philip of Macedon, the bezants of Constantinople and of the Greek Empire, and the florins of Florence are typical of these foreign products. From the first introduction of native gold coins in Britain, however, there was no interruption in their production until 1917, though there were many changes in fineness, weight, and designation.

At the outset, the coins of Henry III were almost pure gold, and the denomination was that of a gold penny. Later the name changed to florin, noble, rose noble, crown, sovereign, and angel. It changed back to sovereign in Elizabeth's reign, to guinea from the time of Charles II to that of George III, and again to sovereign in 1816, when gold became the only standard of value. The fineness was established at 22 carats, or 916·6 parts per 1,000, in the time of James I, and it remained at that figure in all succeeding reigns. Twenty pounds weight (troy) of gold of this fineness coined into 934 sovereigns and one half-sovereign.

In the earlier days the metals alloyed with gold were silver and copper. The latter was added intentionally in order to make a workable and hard-wearing metal; the former was present because of the inadequacy of the refining processes then known. The introduction of the Miller chlorine refining process in 1867 was effective in removing silver from the gold, and from that time onwards copper alone was the alloying metal.

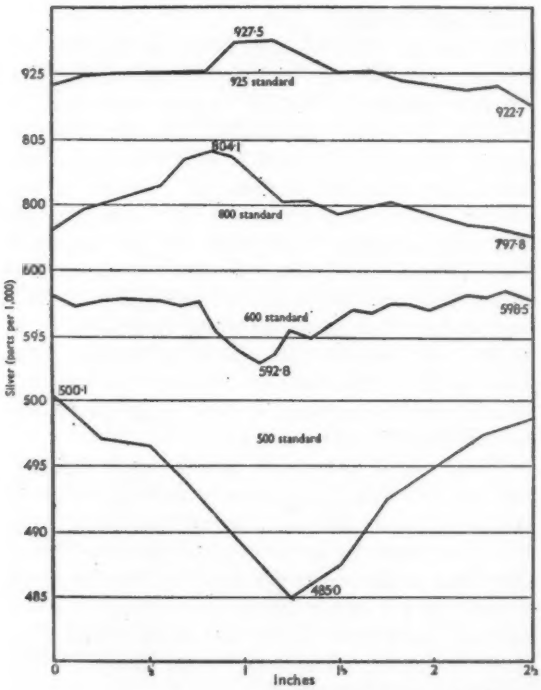


FIGURE 1 – *The diagrams above show how the phenomenon of liquation can affect the composition of a silver-copper alloy at different points across a bar 2½ in. wide. The effect is much more marked with the* 500 *alloy, introduced in* 1920, *than with the old* 925 *alloy.* (*See page* 18.)

The history of the silver coinage in Britain is one of many changes. The fineness of sterling silver as 925 parts per 1,000 was established in Saxon times. The term 'sterling' itself is derived from the Easterlings, who were people of the Low Countries trading in Britain, and who may very possibly have been employed in the making of coins. Afterwards the term 'sterling' became synonymous with standard silver, but it also assumed a second meaning signifying the international currency value of British credit. The term 'sterling silver' is still used, particularly to describe silver wares which are hall-marked as being of the correct 925 standard.

The principal weight employed for weighing gold and silver coin is the troy pound. This has been used since 1527. It is divided into ounces, pennyweights, and grains, a pennyweight being 24 grains. Previously there had been other units, such as the Tower Pound, the Goldsmiths' Pound, and the Moneyers' Pound, one-twelfth of which, or 1 oz., contained only 450 grains, as compared with the 480 grains of the present troy ounce. The pennyweight in this case was only 22½ grains. In Norman times the pound weight of sterling silver was coined into 240 pence. This was the origin of the term 'pound sterling'; nowadays, however, it no longer describes a pound of sterling silver but the purchasing power of a pound note.

Depreciation of the silver coinage began in the time of Edward I (1279), when 243 pence instead of 240 were allowed to the troy pound. Henry VIII increased this to 576 pence, and reduced the fineness to 333⅓, with great profit to his own purse. In the succeeding reign of Edward VI (1550) a minimum was reached when the fineness was allowed to touch 250 parts per thousand. Elizabeth, however, very wisely raised it again to 925, at which figure it remained until 1921. By the time this permanent change took place the relation of money to commodities had undergone such variations that it was no longer possible to revert to the older relation of twenty shillings to the pound troy. It had to continue at a higher figure, first at 60 shillings, then at 62 shillings, at which it

remained for two centuries. In 1816, on the adoption of gold as the only standard in the reign of George III, silver became a purely token coinage, and the pound troy of sterling silver was made to yield 66 shillings.

The weights of the individual coins (those of cupro-nickel also) remain unchanged at the present day and are derived from the pound troy in the way described above. It follows that in whatever way 5s. 6d. (66 pence) worth of silver coins is made up, it will always weigh 1 oz. troy or one-twelfth of a pound troy.

In 1920, when the price of silver rose to over 80 pence per ounce, and it therefore became profitable to melt down silver coins made of the 925 alloy for the sake of the silver contained in them, the fineness was reduced to 500 parts per 1,000, but the weights remained the same. In 1947 silver-containing coins began to be disused, even as a token coinage, and their place was taken by base cupro-nickel coins. This was done on economic grounds and was an outcome of the Lease-Lend agreement made with the United States during the war.

It will therefore be seen that the steps which led to the selection of particular alloys for coinage purposes were not dependent solely on a knowledge of their metallurgical suitability but depended also upon the political or economic exigencies of the times. These factors are still very powerful.

In the middle of the nineteenth century a serious attempt was made to bring about uniformity of both fineness and weight among national coinages. Until then, while the troy system operated in Britain, other systems were in use on the Continent. This provided opportunities for the coinage of one country to find its way into adjoining countries where it had from time to time a greater intrinsic value. Similar difficulties have arisen in recent times within the British Empire. At one time British coins circulated in Rhodesia while the Union of South Africa was still on the gold standard, and coins were smuggled over the border, where their exchange value was higher. In this way the supplies in Rhodesia were so depleted that an entirely new coinage had to be provided.

The Convention of 1865, known as the Latin Monetary Union, was the first serious step towards standardization in Europe. It unified the coinages of France, Belgium, Italy, and Switzerland, the standard for gold being 900 and those for silver either 900 or 835 parts per 1,000, according to the particular country.

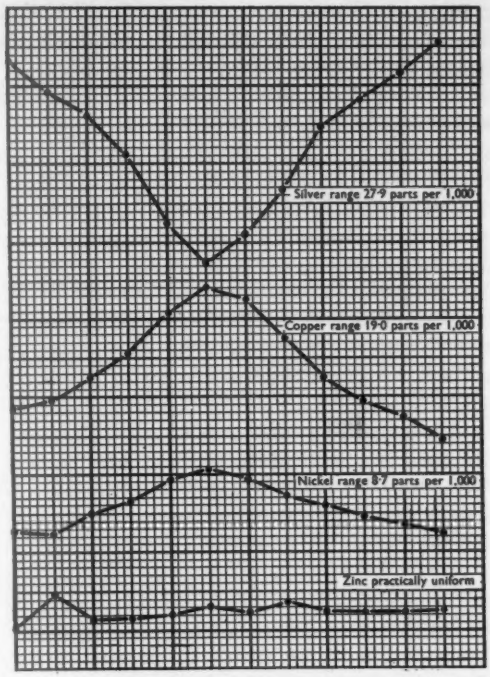


FIGURE 2 – *Variations in the percentages of individual constituents of a quaternary alloy of silver, copper, nickel, and zinc across a rolled fillet of width* 2·375 *in.* (*Smith*).

It is a fortunate fact that silver and copper can be alloyed in almost any proportion to give material suitable for the production of coins. Within recent years even the eutectic (i.e. mixture of the lowest melting-point) containing 72·8 per cent. of silver has successfully been used for coinage, despite its known tendency towards intercrystalline cracking. Since 1921, when the fineness was reduced from 925 to 500 parts per 1,000 in Britain, a third and fourth metal have been added in order to procure a pleasing whiteness, comparable to that of the standard which had been in existence for so long.

In general, the following properties of coinage alloys are desirable. For minting purposes the alloy should have good casting properties, giving sound bars with good surfaces; it should be ductile to ensure easy rolling, uniform in composition, and able to flow when struck between dies. For purposes of circulation the alloys should be durable, sonorous when rung, difficult to counterfeit, resistant to tarnishing, and pleasing in appearance.

It is above all desirable that through the years, whether the composition remains constant or not,

coins should not vary to any great extent in colour and general wearing properties. This condition having been satisfied, it is also desirable that, as William Morris once wrote, 'the workmanship should be good in order that people may have pleasure in things they must perforce use.'

The reduction in fineness to 500 parts per 1,000, decreed by the British Parliament in 1920, presented one of the greatest metallurgical problems in coining since the time of Edward VI, when ideals other than profit-making were probably not so much sought after, and the appearance of the coin was not so important as the swelling of the exchequer.

The introduction of the 500 alloy in 1921 drew attention to a property in alloys which is particularly prominent in those containing silver, namely liquation (i.e. partial liquefaction on heating) and inverse segregation. This phenomenon occurs also in certain types of bronzes.

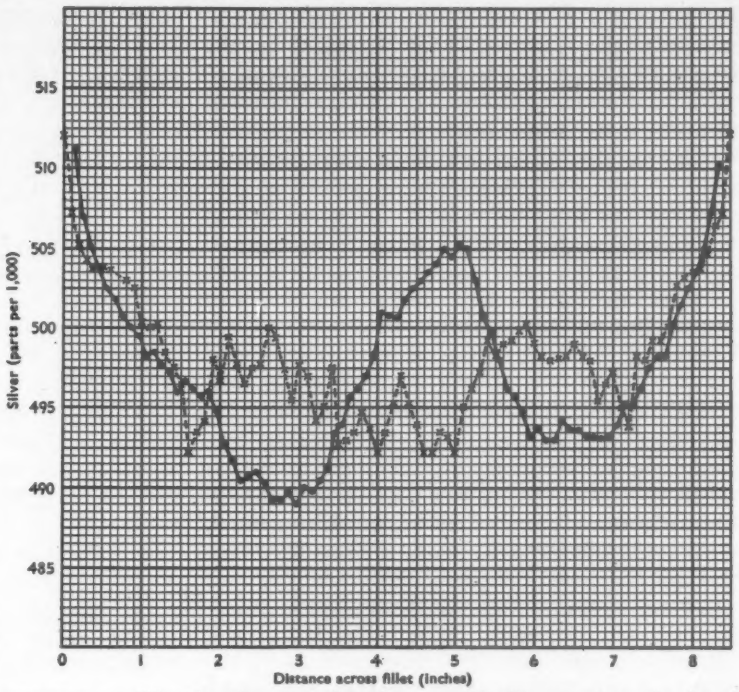


FIGURE 3 – *Liquation phenomena depend to a considerable extent upon the size of the ingot. The diagram above shows how the percentage of silver varies in a fillet prepared from a 12 in. by 2 in. ingot. The alloy used contained 500 parts of silver, 400 parts of copper, 50 parts of nickel, and 50 parts of zinc per 1,000 parts of alloy. The heavy curve corresponds to the middle of the fillet, the broken curve to a line 8 in. below the top of the fillet.*

In the case of copper-silver alloys (other than the eutectic alloy) it is found that one metal or the other becomes more highly concentrated near the outer surface of the bar than at the centre. The metal which segregates in this way is always the one whose addition would lower the freezing-point of the alloy. The eutectic alloy is constant in composition across the section of bar. Alloys containing more than the eutectic proportion of silver (72·8 per cent.) exhibit a concentration of copper on the outside and of silver towards the centre. In those containing less than 72·8 per cent. of silver the reverse is the case. It was into this latter class that the 1921 alloy fell, the variation in fineness between the outside and the middle of a bar 2½ in. wide being as much as 2–3 per cent. under ordinary manufacturing conditions (figure 1). This circumstance had several important effects. It meant that the only method of obtaining a correct sample of coinage bars was to take a sample from the molten metal and to granulate it in cold water, so that complete granulations could be used in the assay. Cuts from the cast bars could not be relied upon as being accurate, though an approximation could be obtained by clipping a portion on the centre-line of the blanks. Segregation made it undesirable to melt the alloy in very large units or cast it into very large bars, as control was then lost of the segregation effects and their influence on the resulting coin could not be predicted.

Although the 925 alloy exhibited a certain degree of concentration of silver along the middle of the bar, the effect was not so pronounced as the reverse one with the 500 alloy. With the 925 alloy it was possible, by careful work, to keep the fineness of individual coins within the limits of ± 4 parts per 1,000 laid down in the Coinage Act. In the case of the 500 alloy these narrow limits could not, however, be maintained, and they were expanded to ± 5 per 1,000 on 12 oz. troy of coins.

The sampling of the finished coins, cut from fillets in two staggered rows, presented difficulties on the same grounds, since some portions of the individual pieces were cut from areas rich in silver and some from areas which were poor in

silver. Theoretically, centre punches approximately of the size needed for the assay should give comparable results, provided the liquation were always regular and the punches lay consistently at a specified distance from the centre-line of the fillet. These factors cannot be guaranteed, however, in actual manufacture. Resort is therefore made to sector cuts made diametrically opposite to each other and each subtending a right angle at the centre. Mathematically it can be demonstrated that a correct assay can be obtained from any blank cut in single row along a fillet by taking three punches, regularly spaced on a concentric circle on the coin, with a radius of $0{\cdot}6R$ (where R is the radius of the coin).

In order to preserve the whiteness of the coins of reduced standard an addition of 10 per cent. of nickel was made to the first series. The production of an initial surface of fine silver, to preserve the coins from tarnish during storage and the earlier stages of circulation, demanded deeper oxidation during the final annealing before stamping, and hence heavier pickling to remove the oxides thus formed. The coins containing nickel have worn well in circulation, but they presented manufacturing difficulties due principally to the mutual insolubility of silver and nickel and the consequent lack of uniformity in physical properties.

The substitution of 5 per cent. of manganese in place of nickel introduced similar production problems, and a tendency to flake was not overcome. It is interesting to note, however, that following a study of the solubility of manganese in copper and of copper in silver, an alloy was made composed of 50 per cent. silver, 8·9 per cent. manganese, and the rest copper, which showed no liquation. The strips were too hard, however, and could not readily be rolled. During the 1914–18 war American metallurgists demonstrated that, by using the purest manganese obtainable electrolytically, the rolling properties could be improved.

An alloy containing equal quantities of silver and copper had many advantages in working, but showed, of course, pronounced liquation. Moreover, the colour of the alloy is markedly pink, with the result that once the initial fine silver surface wore off in circulation the natural colour was exposed, mainly on the parts of highest relief, one of which was unfortunately the nose.

Several years of investigation resulted in the production of an alloy containing 50 per cent. silver, 40 per cent. copper, 5 per cent. nickel, and 5 per cent. zinc. The natural colour of this was pleasing, and near to that of the old alloy containing 92·5 per cent. of silver. Moreover, by ensuring that the nickel entered into the final melt in the form of a primary alloy of copper, nickel, and zinc, which protected it from the silver, no difficulties in melting and casting were encountered. The zinc, it was found, divided itself equally between the silver and the base metals. The range of liquation could be controlled and the legal limits complied with. It is interesting to note that the base metals showed individual characteristics of distribution as depicted in figure 2.

It has already been pointed out that the necessity for controlling the composition of the coinage between the narrow limits defined by law precluded the casting of large ingots, as in these the extent of liquation made control difficult. The effect of the size of ingot, and of the mass of metal generally, on the liquation phenomena is being investigated at present. An early curve obtained by E. G. V. Newman for an ingot 12 in. by 2 in. shows the complexities that are likely to be encountered (figure 3). Temperature gradients

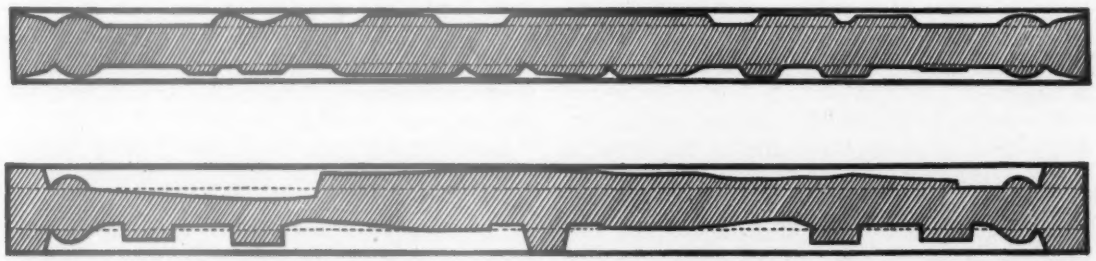


FIGURE 4 – *In designing coins which are struck from the obverse and the reverse at the same time, care must be taken that peaks on one side correspond to valleys on the other, so that no part is weakened by being denuded of metal. No sharpness must be left at the bases of the various reliefs, as these might cause 'ghosts' on the other face. The upper diagram shows the section of a properly designed coin; the lower one shows various defects of the type mentioned.*

within the metal and in the moulds, and the rates of casting and solidification, are among the factors obviously exerting considerable influence on the final result.

The advent of cupro-nickel alloys in place of silver alloys for the principal token coinage of Britain has removed one of the serious difficulties in coining, that of liquation, since copper and nickel are mutually soluble in all proportions. There are, however, other difficulties peculiar to the alloy. It is necessary for the casting to be done at a high temperature (about 1,400° C). Ingots of large cross-sectional area must be cast through pouring cups. For reasons of thermal conductivity the moulds themselves should have thicker walls than usual. Carbon absorption may occur during melting, and this renders the strip brittle. Such brittle strip can usually be reclaimed by re-melting with about 0·2 per cent. cupric oxide or manganese dioxide placed in the bottom of the crucible. If the annealing is done at too high a temperature, say 800° C, the carbon in the blank may become converted into graphite. In this case the blanks are 'biscuit' brittle and must be returned for special treatment in remelting.

The colour of cupro-nickel is initially white, but it tends to become yellowish owing to slight oxidation of the excess copper. This effect is accentuated in hot, damp climates, but has been found to be not so pronounced where circulation is reasonably continuous in temperate conditions.

In most of the essential details the operations of coining are similar to those employed in other industries using non-ferrous metals. Particular attention has, however, to be paid to the preparation of the dies, since the finished pieces have not only to satisfy legal enactments as to weight and composition but also have to be identical in relief and design. It is necessary to reveal the full designs on both obverse and reverse, to portray accurately the essential distinguishing characteristics, and to please—in some measure—the aesthetic sense. The first two conditions are the care of the coiner, the last two that of the artist or designer.

The design of a model for coinage, and also for the making of medals, requires in the artist as well as in the manufacturer an intimate knowledge of the general physical properties of metals and alloys, and especially those of the alloy to be used with the particular dies. In the striking of both the obverse and the reverse at the same time there is an appreciable flow of metal on both faces, from parts of low relief to those of high relief. The designer must take account of this, and so arrange the peaks and the valleys of the two sides that in striking the coin no portion is left denuded of metal by a withdrawal into an opposing relief. He must also, at the same time, ensure that there is sufficient metal to flow into the high-spots so that the designs are uniform everywhere. No sharpness must be left at the bases of the various reliefs, as these might cause 'ghosts' on the other face. The flowing properties of selected alloys, which are related to ductility and elongation, are thus of paramount importance. Figure 4 shows typical examples of such flow and counter-flow.

Artists normally work in one of two media. They may cut an incuse design direct into a piece of softened die steel; this was the method employed by the old master die-sinkers, of whom unfortunately only a few representatives remain. Alternatively, they may make a model in plaster, from which a relief model is made in nickel backed by copper, both deposited electrolytically; the model is very often faced by a hard, thin deposit of chromium. This model is then placed on a reducing machine, the tool of which rotates at high speed. An exact replica of the model, of the correct size of the coin to be struck, is cut by the machine in a piece of softened die steel containing 1 per cent. of carbon. Incuse matrices are produced from this punch, after hardening, by forcing it into a second die blank by means of a succession of blows.

For many years a vigorous controversy has existed between the schools favouring these two methods. The hand craftsmen contend, with some justification, that modern mechanical aids do not give the same finish or yield the same artistry as the slower manual die-sinking of the past. They believe that the feeling of the artist is not transmitted to the final piece, and that there is a consequent loss of the delicacy that characterized the work of the old masters. On the other hand, the need for rapid mass-production of exactly similar dies has demanded some assistance from an accurate machine, and to such help the modern artist is obliged to turn.

In the production of medals for limited circulation the craftsman has more opportunity of expressing himself. The reliefs are greater, and the treatment is more individual. Even here, however, the reducing machine has entered the field because of its adaptability, and because most modern artists have been schooled in relief and not in incuse designing.

The high-intensity flash-discharge tube

J. N. ALDINGTON

The fact that the discharge of electricity through a gas may be accompanied by the emission of light has been well known for many years. Only recently, however, has the discharge been applied for obtaining intense flashes of very short duration. By means of such flashes it is possible to examine, both visually and photographically, a wide variety of transient phenomena. Particularly useful in this respect has been the discovery that by using mixtures of gases, such as neon and krypton, practically white illumination can be obtained.

The discharge of electricity through a gas is generally accompanied by the emission of light. For a given quantity of electricity the intensity of the light is inversely related to the duration of the discharge; if the duration is sufficiently short, the light intensity may be very high. The lightning flash is a vivid example of this phenomenon. It occurs when the electrical charge on a cloud reaches a potential sufficient to ionize the atmosphere between the cloud and earth or between two cloud masses. Circuits and tubes have now been devised which enable controlled pulses of light of very high intensity to be produced by processes not unlike those that occur in nature.

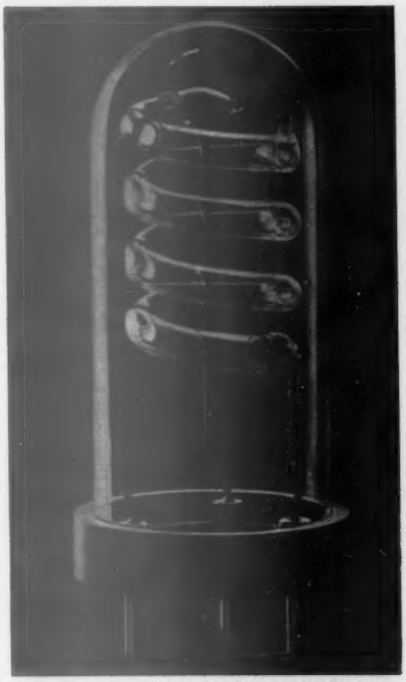


FIGURE 1 – *High-intensity flash-discharge tube capable of discharging* 400 *joules.*

In the laboratory arrangements the electrical energy is generally provided from a capacitor charged to a high voltage, and the light is emitted from a special type of discharge tube connected directly to the terminals of the capacitor. When a voltage high enough to ionize the gas is applied to the triggering electrode of the tube, the consequent sudden and almost complete discharge of the capacitor results in the production of a vivid flash. Of the many gases or metallic vapours which may be used it is of interest to note that the elements krypton and xenon, which occur in such low concentrations in the atmosphere, are among the most suitable for both visual and photographic work. By their use it is possible to obtain luminous efficiencies exceeding 50 l/W (lumens per watt) with a light resembling daylight. The output of a single flash may have a value of the order of 10^5 lumen-seconds, enduring for a few microseconds or extending over a period of several hundred microseconds.

It is this combination of extremely short duration and high efficiency which makes the new flash-discharge lamp such a valuable tool for both visual and photographic investigations. In its simplest form it consists of a glass or quartz tube filled with a suitable gas at a pressure which may lie between that of a few millimetres of mercury and one or more atmospheres. Electrodes are sealed into the ends of the tube, and the voltage which must be applied to them to cause an electric discharge to pass is called the ignition voltage of the device. When a lamp of this type is connected to the terminals of a capacitor charged to a voltage of the order of 75 per cent. of the ignition voltage, little or no current will flow. When, however, the gas within the tube is ionized by the application of a high voltage to a wire wrapped round the tube or to a trigger electrode sealed in it, the capacitor will immediately discharge through the gas with the production of a powerful flash of light. The intensity, colour, and duration of the flash depend among other things on the following factors:

1. The energy of the discharge.
2. The nature of the electrodes.

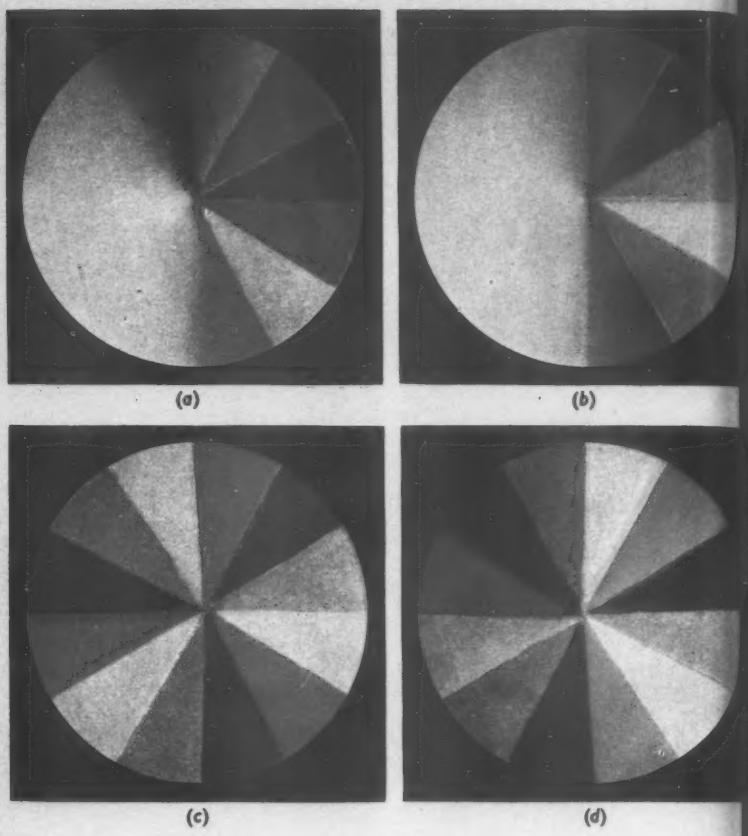


FIGURE 2 (*above*)

(*a*) *Coloured paper cone revolving at* 3,000 *revolutions per minute, illuminated from one side by a tungsten-filament lamp and from the other side by a train of synchronized flashes of light occurring at the rate of* 3,000 *per minute.*

(*b*) *Repetition of* (*a*), *showing phase-shift of cone in respect to the flashing light source.*

(*c*) *Stationary cone photographed by the light from a 'daylight' fluorescent lamp.*

(*d*) *Stationary cone photographed by the light from a tungsten-filament lamp.*

FIGURE 3 (*left*) – *Flash discharge through a mixture of argon and neon.*

FIGURE 4 – *Spectrum of the light from a krypton/xenon flash tube operated at* 5,000 *amperes/cm.*^{2}.

FIGURE 5 – *Photograph of a coloured ball held up in a jet of water. Note resolution of the water jet into single droplets by a flash lasting for about 25 microseconds.*

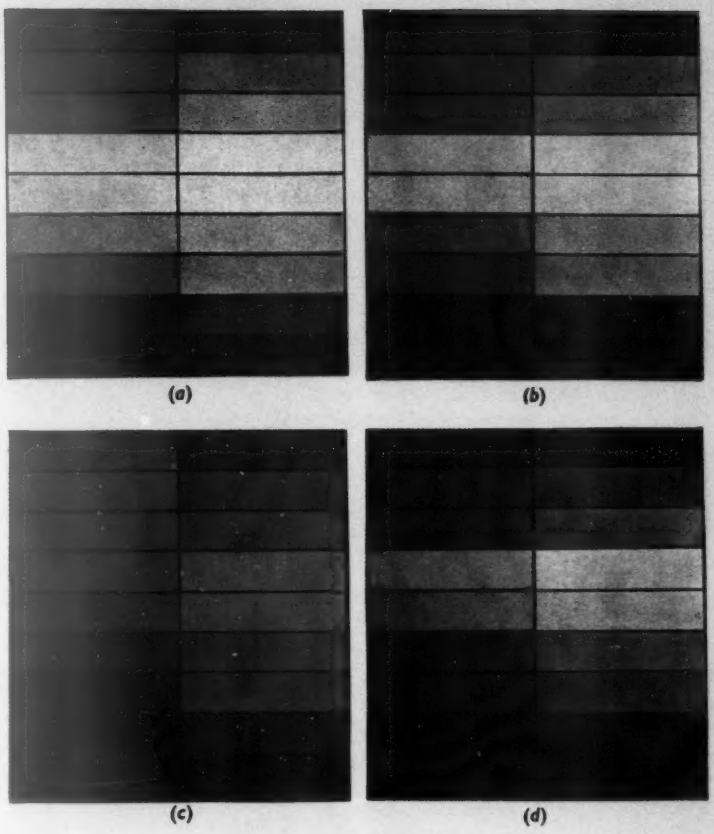


FIGURE 6 (*right*) – *Photograph of Ilford colour-test chart with various sources of illumination.*

(*a*) *Daylight.*

(*b*) *Krypton flash lamp.*

(*c*) *Neon flash lamp.*

(*d*) *Krypton-neon flash lamp.*

FIGURE 7 – *Spectra of three flash-discharge lamps:* (*a*) ***Neon filling,*** (*b*) ***Krypton-neon filling,*** (*c*) ***Krypton filling.***

3. The dimensions of the tube.
4. The nature and pressure of the gas contained in the tube.

Lamps have been produced in Britain capable of dissipating 8,000 joules in 400 microseconds, corresponding to an average power over the discharge period of 2×10^7 W. The maximum light output during the discharge pulse may reach values greater than 10^9 lumens, with a brightness greater than 10^6 candles/cm.^{2}. This is several times the brightness of the sun's disk as viewed from the earth.

The nature and uses of this type of lamp can be illustrated by a short account of some experimental results. Figure 3 shows the effect of discharging the energy from a 10 microfarad (μF) capacitor charged to 3,000 V through a mixture of neon and argon at a pressure of 50 mm. of mercury. The discharge was passed between tungsten electrodes, 10 in. apart, contained within a glass tube 4 in. in diameter. The visible path of the discharge was coloured and of uncontrolled form, and its position varied with each discharge pulse. A controlled path can, however, be readily attained by confining the arc within glass or quartz tubing of relatively narrow bore properly related to the current in the discharge itself. It has been indicated in an earlier section that in order to obtain a considerable light output the lamp must be made capable of handling power which has an instantaneously high value. The way this result has been achieved in practice will be understood by reference to figure 1, which shows a typical lamp capable of dissipating 400 joules in a single flash. Noteworthy features of the design are the length of the discharge path, which is made compact by winding the containing tube into a spiral form, and the size of the electrodes, which are very small considering the high-order currents which flow during the period of peak discharge. The discharge tube itself and the connections to it are protected by an outer domed cover. The main and the triggering electrode contacts are kept as widely separated as possible on the base because of the high voltages which are used. In the case illustrated the triggering electrode consists of a narrow strip of metal wrapped round the outside of the various convolutions of the spiral.

FIGURE 8 – *Photograph, showing contents of a beaker of water flung vigorously upwards, taken with the flash, from a krypton lamp, lasting 100 microseconds. Note the elliptical shape of some of the water droplets, with the long axis in the direction of motion.*

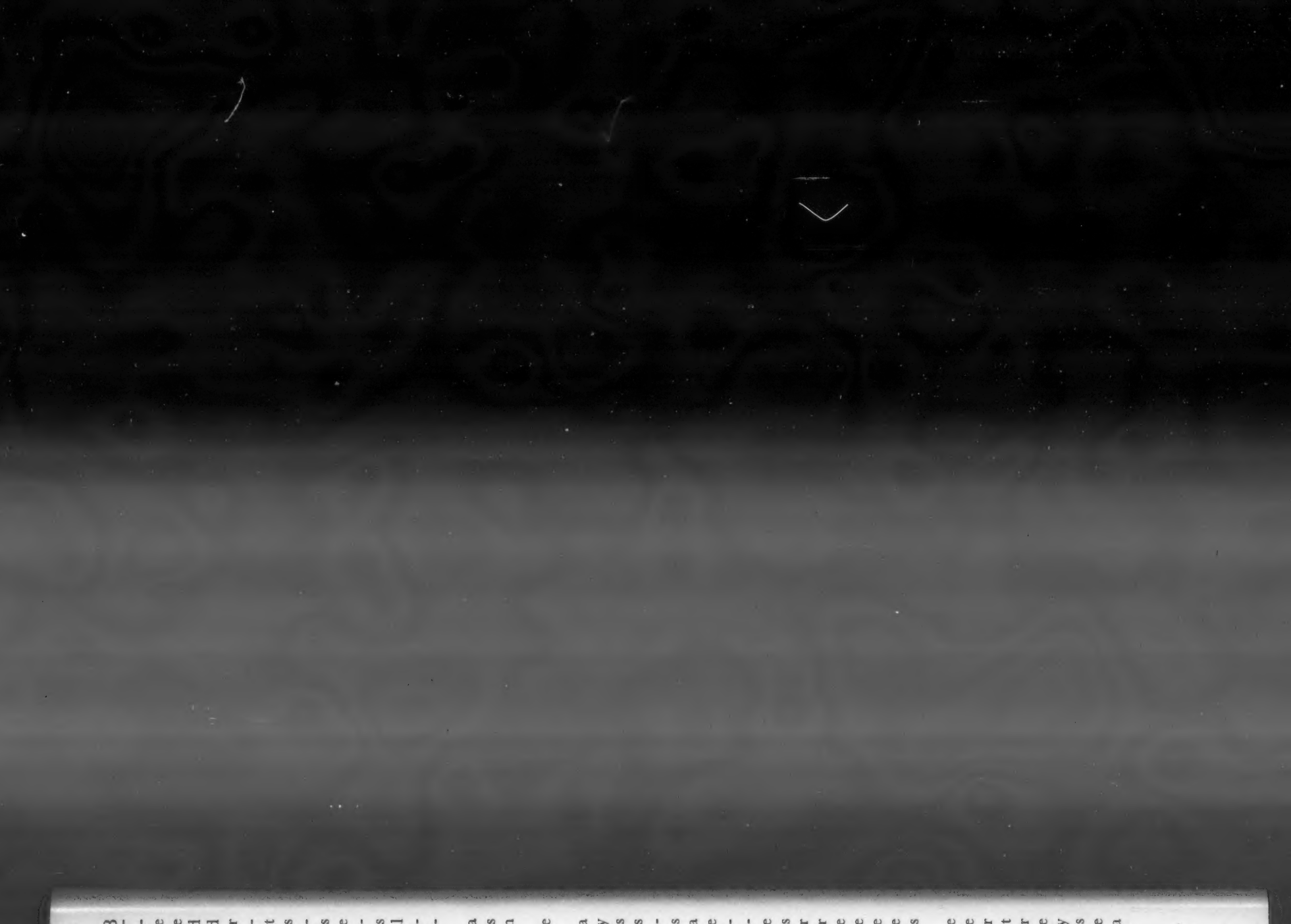
The energy of a charged capacitor is given by the expression

$$E = \tfrac{1}{2}CV^2,$$

where C = capacitance and V = voltage.

It follows that for a given amount of energy to be discharged it is advantageous to use as high a voltage as possible, since E varies as V^2. This permits a smaller capacitor to be used, with a corresponding reduction in the duration of the flash. The use of higher voltages requires the provision of a longer discharge path or a higher gas pressure, so that the striking voltage of the device will always be higher than the voltage to which the capacitor is charged.

The electrical circuit required for the effective operation of these high-intensity flash-discharge lamps is quite simple in principle. The capacitor is charged from a high-voltage direct current supply, such as that provided by a transformer and rectifier. It is always necessary to arrange the circuit so that the capacitor becomes fully recharged in an interval of time materially less than the desired interval between successive flashes of light. The actual instant at which a



given flash occurs is determined by a triggering pulse, which is applied synchronously with the phenomenon which it is desired to photograph or observe. A voltage sufficient to produce a spark about 1·5 cm. in length in air is generally sufficient for this pulse, which may be provided by an induction coil with its primary circuit actuated by the light, or sound, or movement associated with the phenomena to be observed. Means are therefore available for producing isolated flashes of light of sufficient intensity to secure sharp photographs of objects moving at high speeds. Alternatively, to meet the case where it is desired to carry out the visual examination of a rapidly recurring cyclic or periodic motion, circuits have been devised to yield a series of flashes at frequencies which may be varied from one or two per second up to one thousand per second, or even higher. A circuit of this type will also enable a continuous train of light flashes to be produced, each occurring synchronously with the movement of a piece of machinery, thereby providing an illusion of arrested motion. Light-source stroboscopes have of course been known for many years, but in general their light output was very low, making them suitable for use only in a darkened or dimly lit room. With the high-intensity flash tube, however, a stroboscopic illuminator can be produced which not only gives sufficient light to enable moving machinery to be examined with ease under conditions of normal illumination, but renders objects in approximately their natural colours. This important result is achieved when krypton or xenon, or a mixture of these gases, is used in the flash lamp and the current density in the tube is sufficiently high. The spectrum shown in figure 4 was taken with a typical high-voltage lamp operating at about 5,000 amperes/cm.[2].

It will be seen that the spectrum of a krypton-xenon mixture under these conditions is particularly favourable for both visual and photographic work. As the spectrum in the visible region is well filled over the whole range from 4,000 to 7,000 A, the quality of the light can be suitably modified by means of filters if it is desired to take photographs in colour.

Several of these aspects are illustrated in figures 2*a* and 2*b*, which show a shallow cone, rotating at 3,000 revolutions per minute, illuminated from one side by the light from an incandescent tungsten lamp and from the other side by a train of synchronized flashes of light occurring at a frequency of 50 per second. Both the colour effects and the sharpness of the illusion of arrested motion on the right-hand side of the cone are brought out in the illustration. The mixing of the colours to produce an appearance of amber, due to persistence of vision, is clearly shown on the left-hand side of the cone illuminated by the light from the incandescent lamp. The two additional views (figures 2*c* and 2*d*) were taken with the cone stationary under the illumination from a 'daylight' fluorescent lamp and from a gas-filled tungsten-filament lamp respectively.

In the course of developing these high-intensity flash sources it became apparent that the possibility existed of simultaneously exciting the individual spectra of mixed gases or metallic vapours. In particular, in view of the predominance of red radiation in the neon spectrum and the somewhat blue light of the krypton discharge at high current density, investigations were carried out to determine to what extent control could be exercised over the colour and colour-rendering properties of the light from a lamp containing a mixture of these elements. The spectra illustrated in figure 7 indicate some of the possibilities. The illumination of the spectrographic slit was obtained by flashes of light from three high-intensity experimental discharge lamps filled respectively with pure neon (figure 7*a*), a mixture of neon and krypton (figure 7*b*), and pure krypton (figure 7*c*). It will be seen from the middle spectrogram that neon and krypton can be simultaneously excited under the conditions which obtain in these flash-discharge lamps. This result may be of importance in connection with the development of flash-discharge lamps for accurate colour-reproduction at high speed. The apparent lack of radiation in the region 5,000–5,500 A is due to the low response of the photographic emulsion in this region. The table on page 26 shows the trichromatic co-ordinates[1] of the light from the three experimental lamps compared with the co-ordinates of an incandescent radiator at 6,500° K.

The colour photographs of an Ilford test chart reproduced in figure 6 illustrate the suitability of these new flash-discharge lamps for high-speed colour photography. Except in the case of figure 6*a*, where the illuminant was daylight, the photographs were taken with a single flash, lasting for about 100 microseconds, from each of the three special lamps mentioned above. It will

[1] These co-ordinates or coefficients measure the contribution made to the whole colour by the primary red, green, and blue components.

Light Source	*Trichromatic Co-ordinates*		
	x	*y*	*z*
1. Incandescent indicator at 6,500° K..	0·310	0·316	0·374
2. Neon flash lamp	0·580	0·355	0·065
3. Krypton-neon flash lamp	0·320	0·315	0·365
4. Krypton flash lamp ..	0·310	0·310	0·380

be seen that both in the case of the krypton lamp and in that of the krypton-neon lamp the colour-rendering properties of the light as reproduced by Dufaycolour are reasonably close to those of daylight.

The evolution of the high-intensity flash-discharge lamp has enabled improved techniques to be devised for the visual inspection or photographic recording of many different types of transient phenomena. For example, linear forms of lamp have proved of value in the photography of ion tracks in Wilson cloud chambers. Elucidation of the factors influencing atomization of liquid fuels at injector jets is being facilitated by the use of the powerful light pulses from special flash tubes. High-speed photography on continuous-film cameras has become possible, and picture repetition rates of 1,000/sec. are feasible.

Flash-discharge lamps are used in a special photographic zenith tube, now under construction for the Royal Observatory, Greenwich, for the determination of time with high accuracy. The lamp, which is flashed by impulses from one of the standard quartz crystal clocks, illuminates a slit attached to the moving carriage carrying the photographic plate on which the star images are recorded. The image of the slit is focused on a stationary photographic timing plate, across which a number of images are produced. The instrument thus incorporates a high-precision chronograph and, at the same time, a check on the uniformity of motion of the plate carriage is provided.

Max Planck (1858–1947)

On 4th October there died at the age of 89 Max Planck, whom we may properly term venerable for his age, for his achievements, and for the admiration and respect in which he was universally held. As long as science is cultivated he will be honoured as the originator of the quantum theory, to which his claims are undisputed. The enunciation of the quantum principle was not one of those advances where there was a race, in which the actually accepted discoverer arrived a little before his competitors. The discovery was made by Planck alone, in a sense before its time; it caused no sensation, and its significance was realized comparatively slowly. It was the careful, critical, continued examination of the basis of the thermodynamics of radiation that led Planck to the quantum hypothesis, and Einstein, Debye, Born, Bohr, and other great names later showed how wide and how fundamental was its scope. Today it can be said to dominate the field of theoretical physics and to extend beyond that region.

It was Planck's work that brought into prominence the fundamental duality in the theory of radiation, namely the particle aspect and the wave aspect, which have been reconciled only of recent years. It is Planck's work that ultimately underlies all theories of atomic change, nuclear and extranuclear. Another direct consequence of his great discovery is the uncertainty principle, which has disturbed the basis of physical science. It is strange to think that all this sprang from a difficulty in the theory of the distribution of energy in the spectrum of the light from a full radiator.

Max Planck was already well established as a theoretical physicist, and had been many years professor in the University of Berlin, when he first put forward the quantum theory. The many high honours which accrued to him, when the scope of his discovery was realized, included a Nobel Prize in 1919, when he was over 60, and the Copley Medal of the Royal Society ten years later. His simple, upright, modest, yet critical character was unchanged by the world-wide recognition of the importance of his work. The last thirty years of his life were saddened by many family misfortunes and by the political events in his fatherland, which were repugnant to him. Accompanied by his wife, who survives him, he visited England in 1946 for the Newton celebrations and, though feeble in body, showed his accustomed clarity of mind. With him passes one of the great creative figures of modern physics.

E. N. DA C. ANDRADE

Parasitic animals and the world's food

G. LAPAGE

At the present time, when the world is suffering from a general shortage of food, steps have to be taken not only to increase production but to prevent loss and wastage. One of the chief menaces is the parasitic animal, various species of which are responsible for the annual loss of food to the value of hundreds of millions of pounds. In the present article Dr Lapage surveys the problem, explains its gravity, and emphasizes the need for international co-operation.

There is no need at the present moment to stress the difficulties which impede the supply of an adequate diet to the nations of the world. The conservation and increase of supplies of food, their distribution, the regulation of their consumption by the various peoples, the prevention of waste, and a number of other problems, are engaging the urgent attention of experts all over the world. Much has been written about these problems, but comparatively little—or, some would say, all too little—is told to the public about the losses inflicted upon our food supplies by living things which prey upon them in one way or another, whether these be animals which consume them as food, or bacteria, viruses, or parasitic animals and plants which cause disease. These losses are suffered, first, by our crops and, second, by our domesticated animals, which provide us with meat, milk, eggs, and other products.

It is always difficult to assess this damage with accuracy. Probably we shall never know the precise extent of the injury done to crops by living things which either directly consume them or produce disease in them. Estimates of the damage done to domesticated animals by bacteria, viruses, and parasitic animals have, however, been made. Although this article is concerned chiefly with the losses inflicted upon our food supplies by parasitic animals only, it is helpful at the outset to gain some idea of the total losses inflicted by all kinds of disease.

Two estimates, one of the total losses incurred in Britain and the other of those in the United States, will give us in financial terms a measure of the order of the injury inflicted by the combined activities of bacteria, viruses, and parasitic animals. The Second Report of the Committee on Veterinary Education in Great Britain [1], published in 1944, states that the annual loss in England and Wales, due to diseases of farm livestock alone, is 10 per cent. of the output of the meat, poultry, and dairy industries, and represents a loss of nineteen million pounds a year. The National Veterinary Medical Association of Great Britain and Ireland [1] later showed that this estimate was too low, and added evidence that four of the major diseases of cattle alone caused an annual loss of twenty million pounds, of which twelve millions were ascribed to the loss of milk and the remainder to loss of stock. With these statements we may compare the estimate of the United States Bureau of Animal Industry [3], issued in 1942, that the total loss on domesticated animals in the United States through all the diseases listed in the estimate was 418 million dollars a year. W. A. Hagan, a distinguished American veterinary expert, has expressed the opinion [2] that this figure is far too low and should be increased to at least 1,000 million dollars.

Hagan and others have further pointed out that diseases of farm animals affect our food supplies, not only by killing the animals but by retarding their growth and reducing their production of milk and eggs. They may also injure their breeding capacity and render them liable to further diseases. Sick animals require special care and feeding and may cause considerable loss of food materials which might otherwise be converted into meat, milk, and eggs, or diverted to human use. This wastage is by no means negligible. Experiments in the United States, for instance, have shown that whereas 3·1 lb. of feed will produce in 7 weeks a weight increase of 1 lb. in chickens protected from parasites, 4·5 lb. of feed are required to produce a weight increase of 1 lb. in infested chickens. Experiments on sheep and cattle in Britain, the United States, and elsewhere show that the same general conclusion applies to these animals also. There can be no doubt that persistent unthriftiness, differentiated from actual disease or death, is one of the major

causes of the serious loss of food supplies indicated by the figures quoted above. And these, be it noted, are figures of the losses inflicted upon food supplies derived from domesticated animals only. If the losses inflicted upon our crops could be added to them, the total would indeed be startling.

When we inquire into the relative degrees of damage done by different diseases of farm stock it becomes very difficult, if not impossible, to assess accurately the relative importance of diseases caused by bacteria and viruses on the one hand, and those caused by parasitic animals on the other. In one country the former may be the more important, in another country the latter; and unpredictable factors, such as local epidemics, may upset the normal state of things. The estimate mentioned above [3], issued by the United States Bureau of Animal Industry, ascribed an annual loss of 290 million dollars to the various parasitic animals included in that estimate, a figure which is 69 per cent. of the total loss caused by all the diseases considered. In some other countries the relative losses inflicted by these two classes of injurious organisms might well be reversed, but in all parts of the world, and especially in the warmer countries, parasitic animals are responsible for a great deal of the damage. It is, in fact, never easy to assess the relative importance of the bacteria and viruses and the parasitic animals. One reason for this difficulty is that parasitic animals may seriously affect the health of domesticated stock without causing actual disease; the health of the stock may, however, be reduced by them to such an extent that their resistance to diseases caused by bacteria and viruses is lowered, perhaps fatally. Conversely, bacteria and viruses may affect the vitality of animals so seriously that they contract heavy infestations with various other parasites which still further damage their health.

Let us now transfer our attention more particularly to the various kinds of parasitic animals which menace the world's food supplies. Briefly we may say that they belong to four of the main divisions into which the zoologist classifies the animal kingdom. These divisions are:

1. The Protozoa, single-celled animals of which an example is the malarial parasite of man.
2. The Flukes (Trematoda) and Tapeworms (Cestoda).
3. The Roundworms (Nematoda), a group which includes (*a*) the eelworms and their relatives, which attack potato, sugar beet, wheat, oats, barley, rye, and other edible crops as well as many plants of horticultural value, and (*b*) several species injurious to farm livestock.
4. The Insects, Ticks, and Mites, and some of their relatives.

To these in localized areas, and especially in the warmer countries, we may add some kinds of leeches and the few species of blood-sucking bats.

Some estimates of the losses inflicted by particular species of these parasitic animals will reveal the extent of their threat to our food supplies and the saving of essential foods which might result if their attacks could be effectively controlled.

The annual losses caused by various species of protozoa in the United States have been estimated at ten million dollars [3], and half of these losses have been ascribed to the disease of poultry called coccidiosis. This disease is caused by protozoa belonging to a group called the coccidia, one species of which (*Eimeria tenella*) may be so harmful that it has been estimated [8] to kill 12–20 per cent. of all the chicks hatched in the United States. Other species of coccidia attack other domesticated birds and also cattle and sheep, being especially harmful to calves and lambs. Among the protozoa are also the trypanosomes, some species of which cause the diseases called nagana of cattle and surra and dourine of horses; the organisms which cause histomoniasis of turkeys and trichomoniasis of cattle; the species of the genus *Babesia* which cause redwater fever and Texas fever of cattle; and the relatives of the genus *Babesia* which cause the deadly East Coast fever of cattle in Africa (theileriasis) and anaplasmosis. An estimate [3] of the losses due to anaplasmosis in the United States is $100,000 a year, and one severe outbreak of this disease in Kansas in 1944 caused a loss of $2,500,000 as a result of the deaths of the cattle affected [8]. This latter estimate is a good example of the great increase in the losses sustained which may occur when, for any local or other reason, a disease assumes epidemic proportions.

The flukes and tapeworms are responsible for extensive losses of meat and other foods provided by animals, the liver fluke being especially harmful in this way. It attacks the livers of cattle and sheep and may either kill the animal or affect its health so severely that much meat and milk are lost. A statistical analysis [4] of the records of the slaughter of more than 73,000 cattle in England and Wales has shown that this parasite may cause an annual loss of liver substance costing, at retail prices, £200,000. To this must be added the loss of liver extracts for medicinal purposes and the

high, but not easily assessed, reduction of meat and milk. There is little doubt also that the liver fluke may also cause appreciable deterioration of the capacity to produce calves and lambs.

In the United States the losses caused by the liver fluke are proportionately higher. During the eleven years between 1933 and 1943 the livers of 1,400,000 cattle and 60,500 calves were condemned because they were infected with liver fluke, and it was estimated [7] that 1,075,000 lb. of liver were lost annually during this period. The annual loss in live weight of cattle and calves was estimated at about 2,733,000 lb., which amounts to about 1,366,000 lb. dressed weight. The annual loss of food in terms of liver and beef was stated to be 1,220 tons. The milk secretion was lowered by 16 per cent. by heavy infestations with liver fluke, and the breeding activities of the animals were also reduced. This estimate may be compared with the statement made by the United States Bureau of Animal Industry [3] that the annual loss caused by liver fluke and tapeworm in the United States amounted to five million dollars. It is known that in some areas of the United States 50 per cent. of animals' livers have to be condemned because they are infested with liver fluke [5], and this figure may be at times equalled or even exceeded in slaughter-houses in some parts of Britain. We have to remember, of course, that liver fluke disease depends for its distribution upon certain species of aquatic snails, and that its incidence is therefore controlled to a considerable degree by the nature of the country and by climatic conditions. It is a disease especially of damp areas, and this is one of the reasons why it is most prevalent in Britain in north-west England and North Wales. It is, however, also common in South Wales and south-west England, while the areas most free from it are the southern and south-eastern counties. In some parts of Eire its incidence would seem to be even higher than it is in England and Wales.

The group of roundworms includes some of the most damaging pests of food-producing animals, and hardly any country in the world escapes the serious losses which they can inflict. In this group also are the eelworms and their relatives, which do such extensive harm to many of man's essential crops. In Britain the full extent of the damage caused by these species is not yet known, but they certainly severely injure our crops of potato and sugar-beet in some areas. Other species of the roundworms parasitic upon plants attack wheat, oats, barley, rye, tomatoes, and other edible plants, and the horticulturist experiences considerable losses caused by species which attack a great variety of flowering plants.

The roundworms parasitic in farm livestock belong to several species which attack various organs of the body, but probably the most harm is done by the species living in the food canal. Those in the food canals of sheep, cattle, and domesticated birds cause a form of gastro-enteritis which is one of the most serious handicaps of the livestock farmer throughout the world. The National Veterinary Medical Association of Great Britain and Ireland has estimated [10] that the gastro-enteritis caused by these roundworms in sheep alone costs Britain some £348,000 a year, a sum which is about one-third of the total cost of the ten major diseases from which British sheep suffer. To this loss must be added the losses due to the similar disease in cattle and also that caused by other species of roundworms which attack cattle or sheep or both. Among the latter species are the nodular worms which render the intestines of sheep useless for the manufacture of catgut and other products, and the hookworms which suck blood.

Many species of roundworms consume blood, but the hookworms remove especially large quantities of it. Anaemia is therefore one of the common symptoms of disease caused by the roundworms which live in the food canal. The nodular worms also unfavourably affect the condition of the animals in which they live, and it has been estimated [9] that they cause in the United States a loss of 45,000 tons of mutton annually, not to mention a further annual loss of 6 million dollars due to damage to the intestines used for the manufacture of catgut. Nodular worms may damage the livers of the animals in which they live, and thus add appreciably to the losses caused by liver flukes.

Another roundworm (*Onchocerca gibsoni*), which is sometimes called the nodular worm of cattle because it causes the formation of nodules in the skin and underlying tissues of these animals, inflicts severe losses in Australia [11]. Beef carcasses have to be mutilated by the excision of the nodules before they can be exported to Britain, and briskets may have to be removed. As many as 80 per cent. of the cattle in central and north Australia may be thus affected [6], so that the losses may be very great. They are all the more serious because this roundworm does not occur in Argentina, a country which is one of Australia's chief competitors in the beef export trade. In

addition to the species just mentioned, other kinds of roundworm do appreciable damage in various parts of the world. There are, for instance, the giant kidney worm, which attacks the kidneys of pigs, the large roundworm which lives in the intestines of these animals, and other species which live in the intestines of poultry and other domesticated birds. An idea of the overall damage inflicted by roundworms as a whole may be gathered from the estimate [3] that they are responsible, in the United States, for a total loss of 110 million dollars every year.

The large group of animals which includes the insects, ticks, mites, and their relatives may affect our food supplies in several ways. First, they may themselves consume human and animal foodstuffs. Examples of this kind of damage are so familiar that we need only mention the enormous damage inflicted by locusts, and the losses due to the many insect pests which attack our crops. Less well known is a second type of damage caused by insects, ticks, and mites which are temporarily or permanently parasitic on the exterior of the bodies of farm livestock. These species harm animals and birds in at least three ways: (1) they annoy and irritate to such a degree that the animals suffer from this cause alone; (2) their young (larval) phases may be parasitic in the internal tissues of the animals; and (3) they may transmit to the animals other kinds of parasites which cause serious diseases. Some species of them inflict more than one of these kinds of injury. The extent of the first-named kind of harm is not, perhaps, always realized. Animals and birds which are continually being bitten by blood-sucking external parasites such as mosquitoes, lice, and ticks not only lose blood and suffer from infected bites or sores produced by scratching, but are also restless and lack sufficient sleep. Consequently they do not feed normally and fail to thrive. Nor is this kind of injury inflicted only by biting and blood-sucking species. Some kinds of insects, such as the warble flies, whose larvae develop inside the bodies of cattle, do not bite their hosts, merely laying their eggs upon their hairs or skin, but the animals are thrown by their approach into a state of unrest. They may even stampede and rush wildly about, giving the impression that they are trying to avoid the flies; or they may take refuge in water and shady places, suggesting to the observer that they are aware that some species of warble flies lay their eggs only on the legs or lower parts of the body. The animals thus affected do not feed properly and therefore do not produce so much meat or milk. Horses may be affected in a similar way by horse bot flies. It is difficult to estimate the reduction of food supplies caused in these ways, but an idea of its extent may be gathered from one estimate [3] which places the damage done in the United States by the external parasites of poultry at 85 million dollars a year.

The damage inflicted by the larval phases of insects and other arthropods upon the internal tissues of farm livestock into which they penetrate may be much more serious than that which is inflicted by external parasites. In this category we should include the mites which cause the various forms of scabies, because these mites live, not on the exterior of their hosts, but actually in the tissues of the skin. Here also we include the larvae of warble and bot flies just mentioned. The larvae of the former, after a period of life in the interior of the bodies of cattle, appear under the skin along the backbone, where their presence causes the formation of abscesses, in the pus of which the larvae live. They cut holes in the skin in order to obtain oxygen from the air, thus doing considerable damage to the hides. In addition, the meat around the abscesses is rendered unfit for human consumption. The total damage caused is therefore considerable. The United States Bureau of Animal Industry [3] assesses its cost at 65 million dollars a year, and in other countries the harm done is proportionately high. The larvae of the screw-worm flies, and those of the blowflies which attack sheep and cause the formation of sores and abscesses in the skin, also do extensive harm. Similarly the larvae of the sheep nostril and nasal flies, which burrow into the nasal sinuses and may attack the brain itself, cause heavy losses in the form of poor condition or actual death. In the United States hornflies are serious cattle pests, and the buffalo fly is spreading in Australia, where it attacks cattle.

The third form of damage inflicted by blood-sucking insects, ticks, and mites, namely the harm caused by their introduction into farm livestock of other kinds of parasitic animals, can hardly be estimated. Examples of diseases transmitted to farm livestock have been given earlier in this article. Many species of ticks are especially harmful in this way, because some of the causes of disease transmitted by them are passed from one tick generation to another. If we could get rid of the ticks and also of the insects injurious to farm livestock, the majority of which belong to the group of two-winged insects (diptera), we should

be able to eradicate many of the most serious diseases of farm animals.

Throughout this article an attempt has been made to focus attention upon the parasitic animals rather than upon the bacteria and viruses which affect the food supplies of the world. If the food supplies of Britain or any other individual country had alone been considered, the picture would have differed in some details, because in some countries, and even in some areas of each country, different species of parasitic animals cause greater losses than they do elsewhere. Nowadays, however, it is the world picture of food supplies that matters most. Lack of space has prevented discussion of one important feature of it, namely the damage which may be inflicted upon foods after they have been gathered.

At first sight the picture presented is not a cheerful one, but we may take comfort from the reflection that it is a picture of one aspect only of a many-sided complex, the full consideration of which would require a volume. It has not been possible, for instance, to discuss the important implications of the fact that the study of parasitic animals and their control is still so young a branch of science that the major advances in it have been made within the last fifty years or so, many of them during the last decade. Nor has it been possible to discuss the implications of the recent discoveries of such powerful antiparasitic weapons as Gammexane, D.D.T., the sulphonamide drugs, phenothiazine, hexachloroethane, and other substances, some of which promise to give us, when we have learnt how best to apply them, a much greater measure of parasite control. Not less important, and possibly in the long run more important, are effective improvements in our methods of managing farm livestock and crops, some of which have been specifically devised to combat the organisms which cause disease. The contributions made by the study of animal and plant nutrition are proving to be specially important in this respect. These improvements are based upon biological studies of farm animals and crop plants and of the organisms which attack them, and are among the finest fruits of the modern co-operation between the veterinarian, the physician, the biologist, the biochemist, and the biophysicist.

There is little doubt that the co-ordination of scientific effort will eventually give us all the necessary control of the menaces to our food supplies indicated in this article. From its haunts in the wilds of Brazil a species of malaria-carrying mosquito was largely eliminated, and this amazing feat was recently repeated in Egypt. Tuberculosis of cattle, imported into the United States from Europe during the nineteenth century, has now been virtually extinguished in that country, and this has been done in spite of the fact that we know of no drug which will cure this disease of man and animals. Several factors have co-operated in the accomplishment of these tremendous achievements, but not the least of them have been hard work, the co-operation of men with one another, the will to succeed, and the necessary money to put into action the measures which scientific research has indicated. If the same degree of effort, the same willing international co-operation, and the same resources of money and knowledge are applied to the biological menaces to the world's food supplies, there is little doubt that, whatever else may happen to the food of the world, it will not in the future suffer the enormous losses which now deplete it at its very sources.

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Tropical fruits: their storage and transport

C. W. WARDLAW

Existing methods of storing and transporting tropical fruits have already made some of them abundantly and cheaply available in temperate countries. Even with more familiar fruits, however, such as bananas, grapefruit, and oranges, many problems still remain to be solved. Although the general cold storage requirements of other fruits, such as the avocado, have been ascertained by *ad hoc* experiments, comparatively little is known of the changes associated with their growth to maturity and subsequent ripening.

The Englishman who has read and heard of the many delectable fruits to be found in tropical and subtropical regions may perhaps occasionally wonder why—times of war and war's aftermath apart—so few of these exotic commodities reach his own temperate land. With bananas, grapefruit, oranges, lemons, and pineapples he is, of course, familiar; and in small quantities, at high prices, there are avocados, mangoes, limes, mangosteens, and persimmons for the connoisseur. But what of the others? All those tropical fruits with names that excite the imagination and stimulate the palate: custard apples, sweet-sops and sour-sops, papayas, durians, granadillas, guavas, jujubes, lychees, loquats, pomeracs, sapodillas, passion fruits, and a dozen others: are these only to be savoured in the mind of the reader of travellers' tales? And is he never to have a helping of yam or bread-fruit at his own table? Clearly this is a matter that deserves some consideration.

In point of fact the situation is one of some complexity, combining as it does both commercial factors—the business of growing, transporting, storing, and selling the fruit in competition with the many excellent fruits produced in temperate regions close at hand—and biological factors. It is with the latter that we are principally concerned here. In practice, any comprehensive investigation of fruit in storage involves a consideration of their physiology throughout growth, ripening, and senescence, and of the fungi and bacteria which may bring about their decay. The effective means of overseas transport is the refrigerated ship, the holds being maintained at temperatures suited to the perishable commodity being carried. For tropical fruits, investigations have been carried out in Trinidad, B.W.I. (the Low Temperature Research Station of the Imperial College of Tropical Agriculture), and in Jamaica, India, South Africa, and Australia. These researches are comparable with those undertaken by the Department of Scientific and Industrial Research (Food Investigation Board) in Britain for temperate fruits.

SOME GENERAL CONSIDERATIONS

The major tropical fruits requiring refrigerated transport are bananas and citrus. Bananas rank as one of the most important crops throughout tropical and subtropical regions, and in some countries constitute the chief source of agricultural wealth. From small initial experimental shipments large and important export industries have developed in different parts of the world in the course of a few decades, thanks to the advance of refrigeration technique. All fruit commodities carried on refrigerated ships differ from animal commodities—beef, mutton, and game—in one important respect: they are alive. They are also, as a rule, not fully ripe or, as in the case of the banana, quite unripe. As a result they cannot be transported at very low temperatures. In point of fact it would be more exact if one described tropical fruits as being carried in *cool* storage rather than *cold* storage. Thus the Gros Michel or Jamaica banana is carried at a temperature of 53° F, mangoes at 48° F, and so on, as compared with carcasses at freezing-point or still lower temperatures.

As noted above, tropical fruits for export are harvested somewhat immature; being still alive, they require environmental conditions during storage which will permit of approximately normal though retarded maturation, so that all the appearance, flavour, texture, aroma, and other qualities for which they are prized will be preserved. If fruits are stored at too low a temperature, the ripening trend is abnormal, and various so-called 'chilling injuries,' inimical to the appearance and flavour of the fruit, result. If the storage temperature is not sufficiently low, maturation proceeds too rapidly, tropical fungal pathogens

are liable to make inroads, and extensive wastage may result.

Although the storage temperature required by a particular tropical fruit, harvested at a certain maturity, can be determined by simple trial-and-error tests, a knowledge of what is actually happening within the fruit during its slow maturation in cold storage and subsequently during ripening at higher temperatures (for the banana, 62–70° F) is less easily obtained, and sets the plant physiologist a problem of a high order of complexity. So also the pathologist has his special problems: some of the parasitic micro-organisms are present as spores on the surface of the fruit and gain access through wounds and abrasions; but others have long been present within the cells of the fruit skin as inhibited or latent infections, and renew their growth and parasitic activity only when a certain stage of maturation has been reached. In other words, as the fruit ripens the environment of the pathogen changes from one less favourable to one more favourable to its development. Studies of a far-reaching kind are thus essential.

Even a small amount of practical experience makes it clear that, if we are to understand what happens when a fruit slowly ripens in cool storage, we must also have knowledge of the antecedent developments—the formation of the fruit and its growth to the time of harvesting. Our investigations, in fact, tend to be pushed farther and farther back. Indeed, experience has taught us, both for tropical and for temperate fruits, that environmental factors (soil and climate) have a marked effect on the behaviour of fruit during cold storage and subsequent ripening and must be duly considered by the investigator. For example, grapefruit grown in dry subtropical regions can be stored without injury at temperatures below 40° F, whereas those grown under moist tropical conditions suffer chilling injuries of various kinds if kept at temperatures below 45° F. Not least, genetical characters must not be overlooked. To take a simple case by way of illustration: whereas the Jamaica or Gros Michel banana requires a storage temperature of 53° F, the Cavendish or Canary banana can withstand rather lower temperatures, while the Lacatan—a fruit of excellent flavour and aroma—must not be subjected to temperatures below 58° F.

The maturing fruit might perhaps be described as a variable biological system, undergoing a succession of changes of a complex nature, in relation to inherent biological factors and factors in the environment. The relevant investigations will thus include observations of histological changes and studies of respiration, transpiration, and metabolic processes during growth, ripening, and senescence. At present it is not always possible to translate scientific knowledge into practice. From the commercial standpoint, the final arbiters of successful storage and ripening are the eye and the palate.

PHYSIOLOGICAL STUDIES

So far, only a very few tropical fruits—chiefly the banana and citrus fruits—have received close physiological study. Some others, including avocados, mangoes, and pineapples, have received some attention, mostly in relation to particular physiological aspects, for example, respiration, and the content of sugar and acid or oil during ripening. But tropical fruits in general still remain practically untouched by physiological investigation. This may be indicated as a field affording magnificent opportunities for research on materials as varied as they are interesting. Here an account of the best-known material—the banana—will be given, with occasional references to other tropical fruits. Broadly speaking, investigations of respiration, transpiration, and biochemical changes constitute the means by which information bearing on practical aspects can be obtained.

The fact which is probably most impressive to the layman is that the banana, intended for export from the West Indies or Central America

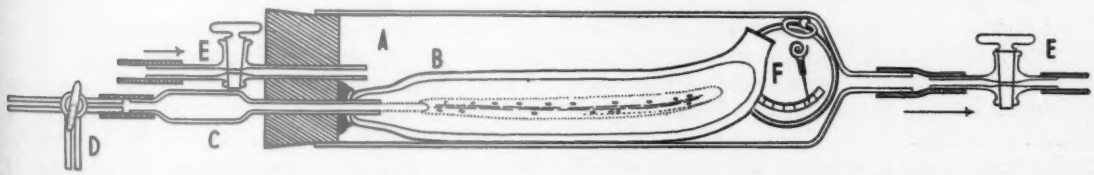


FIGURE 1 – *Arrangement of apparatus to permit both measurement of the respiration rate and analysis of the internal atmosphere of a banana.* A, *respiration chamber;* B, *banana in longitudinal section, showing the cavity made by the cork-borer;* C, *sampling tube with* D, *3-way stopcock;* E, *2-way stopcock;* F, *paper hygrometer.*

FIGURE 2 – *The mango* (*Anacardiaceae:* Mangifera indica).

FIGURE 3 – *The avocado* (*Lauraceae:* Persea americana

to Europe, is harvested while still quite green and immature, at a stage described as 'three-quarters full' by the trade. As a matter of fact, such a fruit is only a little more than half-grown. Growth studies of the banana bunch, from the time of 'shooting' (i.e the appearance of the bunch at the crown of the plant) up to the maximum size at which the bunch could be harvested for storage, show that a three-quarters full bunch is capable of a further increase in weight of approximately 50 per cent., the edible matter (the pulp) increasing by 60 per cent. Thus the later the fruit is harvested, the greater is the proportion of potential edible matter. There is the further, not unreasonable, assumption that the eating quality may also be improved. Bunches left on the plant eventually show incipient ripening, the colour of the skin changing from green to greenish yellow or yellow and the pulp becoming soft and sweetish. Such fruits are not quite ripe enough to be eaten. Before this stage is reached the weight of the bunch tends to pull over or break the fruit stalk or trunk, and insects and animals make inroads on the ripening fruits. Such fruits are almost twice as heavy as standard fruits harvested at three-quarters full.

During the development of the individual fruits, sugar remains at a very low concentration but starch is rapidly accumulated, especially during the two or three weeks that follow the attainment of the three-quarters full stage. Respiration proceeds at a steady rate during this period. With the onset of ripening there is a marked transformation of starch into sugar and a rise in respiration rate.

Banana fruits, when selected for overseas transport in refrigerated holds at 53° F for a voyage lasting from twelve to fifteen days, are firm, green, and immature. During this period respiration proceeds at a low, steady rate and the composition of the fruit remains practically unchanged. This, indeed, is the purpose of holding fruit at a suitably low temperature—to delay the onset of maturation until after the fruit is discharged at its destination. But soon after the fruit is placed in ripening rooms at a higher temperature (62–70° F, according to the condition of bunches and marketing requirements), ripening begins.

FIGURE 4 – *The papaya* (*Caricaceae:* Carica papaya).

FIGURE 5 – *The custard apple, sugar apple, or sweet-sop* (*Annonaceae:* Annona squamosa).

Biochemical, respiration, and transpiration studies have shown that this is a complicated process, involving many changes which normally take place in an orderly sequence. As in other fruits, ripening in the banana proceeds from the central placental region (where the abortive seeds can be seen) through the outer pulp to the skin; it takes place a little earlier at the distal or stylar end than at the proximal or stem end.

In respiration studies, the rates of liberation of carbon dioxide and of uptake of oxygen at the fruit surface are measured as affording a useful general indication of the biochemical activities taking place within. Such studies show that the respiration rate undergoes a marked change with the onset of ripening. There is a rapid rise in the rate of utilization of oxygen and output of carbon dioxide and a rise in pulp temperature. Respiration now proceeds at the new high rate and the fruit is seen to be softening ('sprung'), colouring, and ripening. This rapid change from the unripe to the ripening state is known as the climacteric phase. Biochemical studies reveal that a whole series of chemical reactions is now proceeding rapidly. These include a decrease in total dry matter, the hydrolysis of starch, an increase in sugar content, acidity and glycoside glucose, and many other interesting changes. As the fruit becomes eating-ripe, over-ripe, and finally senescent, the several curves for respiration rate, percentage sugar content, etc., are found to follow characteristic trends.

An important aspect of this work was to investigate the relationship between respiration rate and change in chemical composition during ripening. In the laboratory, as observations of rate of respiration are usually carried out continuously on single fruits, such fruits are not available for chemical analyses. This difficulty was overcome by a simple device. It was found that by inserting small tubes into the banana fruit, samples of the internal atmosphere could be withdrawn and analysed (carbon dioxide and oxygen); measurement of the carbon dioxide liberated at the fruit surface could also be obtained from the same fruits (figure 1).

It was found that the climacteric rise in carbon dioxide output was slightly preceded by a sharp

rise in the internal concentration of carbon dioxide and by a marked decline in the oxygen concentration. In brief, the curves of internal concentrations of carbon dioxide and oxygen in individual fruits, under controlled conditions of temperature and humidity, yielded exact information of the stage of ripening reached at any particular time. Fruits at a known state of ripeness were thus available for biochemical analysis. By using a sufficient number of strictly comparable fruits it was thus possible to correlate closely respiration and biochemical data. Some typical results are illustrated in figure 6. Many other points of interest were also brought to light. For example, it was found that during the post-climacteric period the softening tissues offered greater resistance to the movement of gases, and a negative pressure, which could be measured by means of a manometer, was developed within the fruit.

The effect of prolonging the cold-storage period beyond that usual for each grade, and the chemical nature of the abnormalities in the eating and other qualities associated with the resulting chilled condition, have been investigated. There is evidence, from both respiration and biochemical studies, that those fruits which show 'physiological injury' have already begun to ripen during the cold-storage period. Ripening does not, however, follow the normal trend: the skin colour becomes abnormal (a rich bronze colour may develop) and the pulp flavour is poor, astringent, and flat. The biochemical changes involved are complex and obscure, but it is known that the rate of starch hydrolysis is low as compared with that in normal fruits, and the acid and glucoside content tends to be high. Extreme chilling results in a very considerable retardation of ripening and, in extreme cases, in failure to ripen.

With the onset of ripening the several associated fungi become active. Some of these are no more than saprophytes capable of exploiting the ripe sugary tissues of skin and pulp after gaining access through cuts and abrasions. Much more interesting and in some ways more important fungi are those which have long been established in the epidermal cells of the pulp and skin as latent infections. Of these the most significant commercially are *Gloeosporium musarum* (the anthracnose fungus) and *Piricularia grisea* (causing pitting disease). Once these organisms have penetrated the epidermis of young fruits, the living cell, in which the small fungal germ-tubes persist, constitutes the environment of the fungus. In this environment, during the long period of growth to harvesting maturity, the fungus apparently remains in a static condition. But with the arrival of the post-climacteric phase, and the attendant changes in the physical and chemical state of the tissues, the environment becomes favourable to the further growth of the pathogenic organism: it now spreads to neighbouring epidermal cells and into the tissues below, producing characteristic lesions. Such latent infections, their development during ripening, and their control, still require investigation. One of the most interesting points so far noted is the regularity with which the appearance of anthracnose spots coincides with a certain stage of ripeness as ascertained by observation of the internal gas concentrations. In the banana and papaya, for example, it is possible to predict, from a knowledge of the trend of the internal concentration of oxygen, exactly when anthracnose spots will appear. In passing, it may be noted that latent infections of *Gloeosporium* and other fungi may be a serious cause of wastage in avocados and mangoes. In both of these, as also in the banana, chilling injuries render the fruit much more susceptible to the development of this disease.

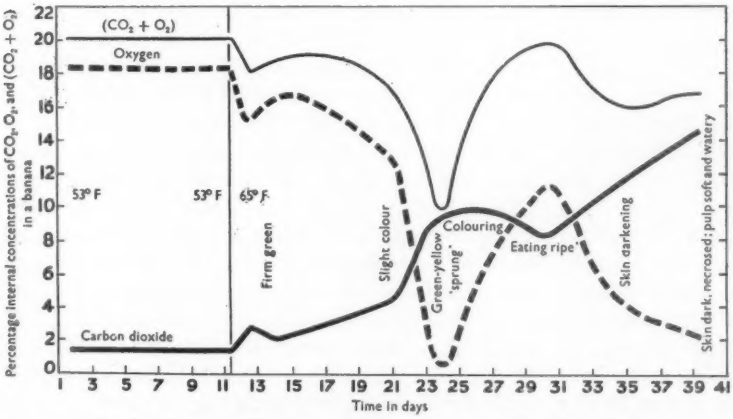
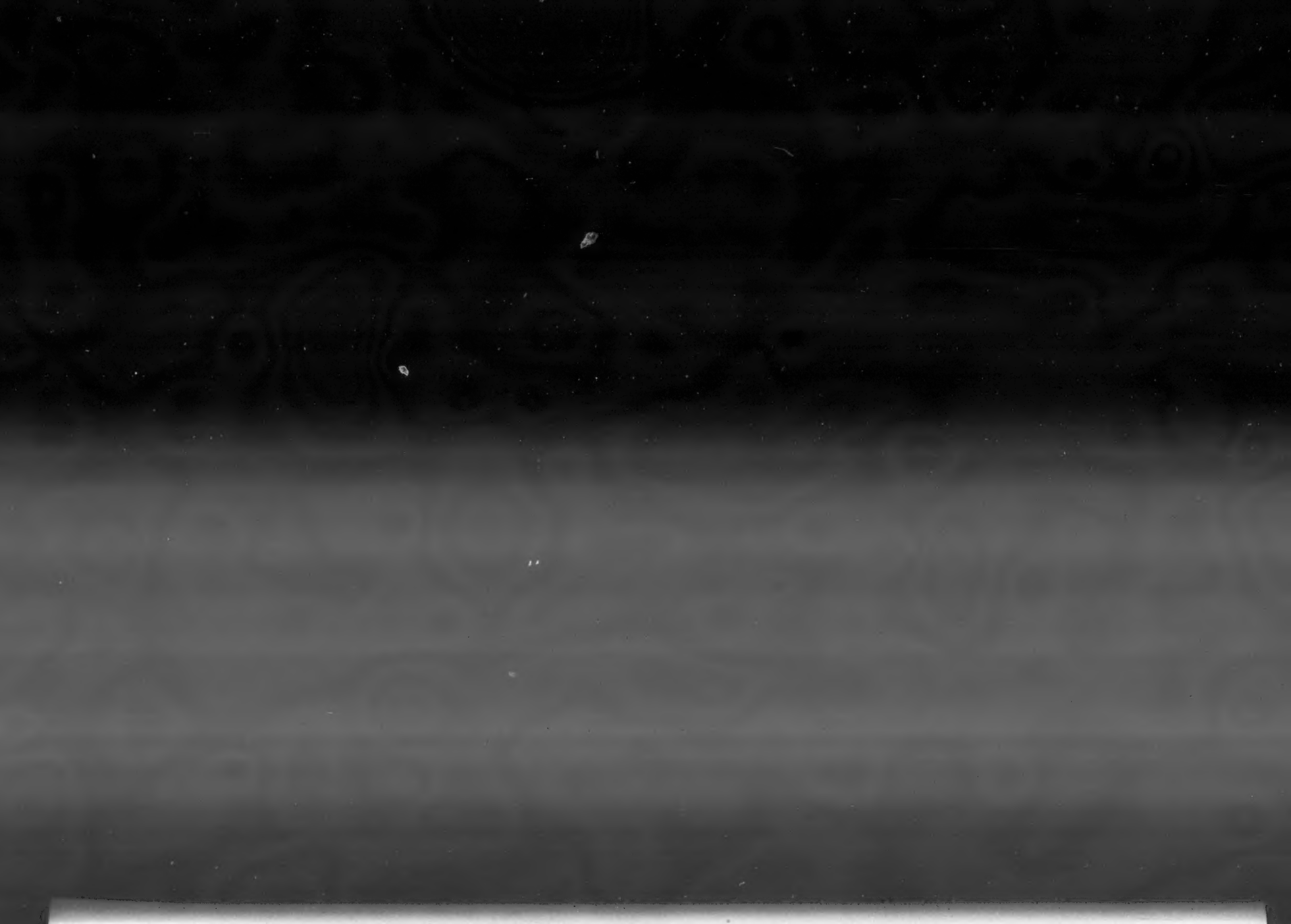


FIGURE 6 – *Internal concentrations of CO_2, O_2, and $(CO_2 + O_2)$ in a heavy three-quarters full Gros Michel banana during cold storage and ripening.*

GAS STORAGE

The essential feature of transporting bananas in refrigerated holds is to delay the onset of ripening until the fruit is discharged at its destination. With relatively thin grades, harvested



three-quarters full, this can usually be achieved by refrigeration alone during a voyage of up to sixteen or seventeen days. Heavier grades of fruit, described as 'full' and 'heavy full,' however, begin to ripen during a similar period and chilling injuries result. Yet, as we have seen, there are good reasons why the transport of such grades of fruit should be attempted. It has been suggested that gas storage in conjunction with refrigeration, which has already proved successful with apples, might also be applicable to the banana. In fact, several workers have shown that this useful result may well be realized. Success would mean that a larger and possibly a better banana could be made available on the present markets, or that the present grades could be transported from more distant centres of production. The same methods may also be extended in due course to other tropical fruits, e.g. mangoes, avocados, etc.

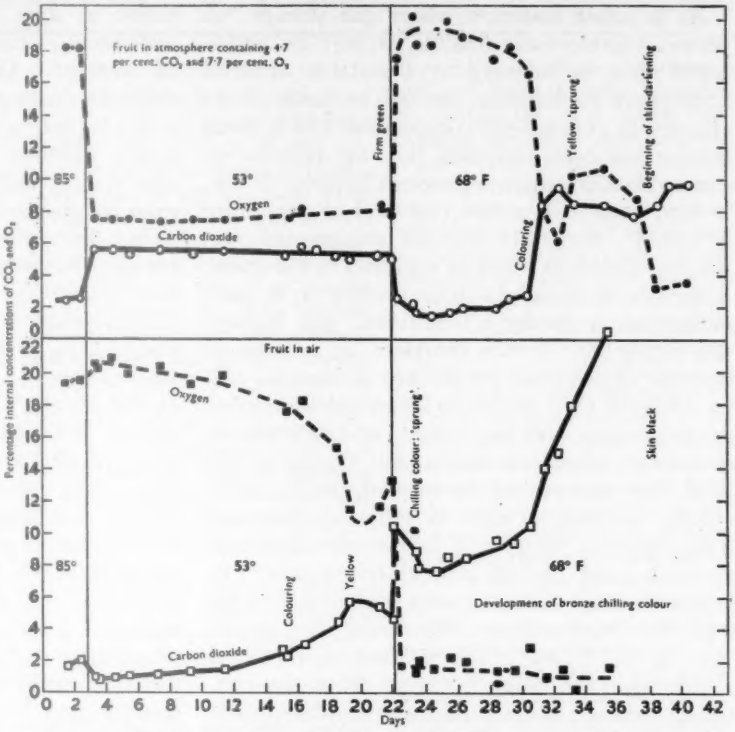


FIGURE 7 – *Storage of bananas (gathered at 85° F) in an artificial atmosphere* (above) *and in air* (below) *at 53° F, followed in both instances by ripening in air at 68° F. The fruit stored in air became chilled and showed abnormal trends in the internal concentration of O_2 and CO_2: gas-stored fruit was normal.*

Observations have been made on the retardation of ripening effected in heavy grades of fruit by refrigeration at 53° F in conjunction with different supplied gas mixtures, and by artificial atmospheres produced by restricted ventilation. In these experiments the trends of the internal gas concentrations during storage and ripening were ascertained and proved of great interest and value. Only the briefest indication of the data obtained can be given here. In heavy three-quarters full fruit, rapidly cooled to 53° F and held at that temperature for twenty days, gas mixtures containing 5 per cent. carbon dioxide and 7–12 per cent. oxygen produced a notable retardation of ripening without injurious effects, the best results being obtained at the lower oxygen concentration. The fruits were subsequently ripened in air in the normal way. As compared with the control fruit in air, in which severe chilling injury was sustained, the gas-stored fruit ripened to a good yellow colour; it showed no evidence of chilling, the palatability, bouquet, and mealy 'break' being those of normally ripened fruit. The different metabolic trends of gas-stored fruit as compared with fruit in air are clearly illustrated in figure 7. In somewhat similar experiments, heavy three-quarters full fruit was stored in oxygen concentrations of 6 and 12 per cent. (in nitrogen). The ripening data showed that a reduction in oxygen concentration from 21 per cent. to 12 per cent. did not afford adequate retardation of ripening during cold storage, whereas a reduction to 6 per cent. afforded a good retardation without injurious effects. Conclusive evidence was obtained that where ripening had already begun, refrigerated gas storage was ineffective: the fruit continued to ripen during cold storage. An important point, particularly from the commercial standpoint, was that although this fruit ripened to a product of excellent colour and texture, the pulp was flavourless. Even high concentrations of carbon dioxide and low concentrations of oxygen did not retard the ripening of heavy grades of fruit in which ripening had already begun.

As in other instances where gas storage has proved commercially feasible, it may be anticipated that, in arriving at a suitable artificial atmosphere for bananas, use will be made of the changes in atmospheric composition which result from respiratory processes, i.e. an increase in carbon dioxide and a decrease in oxygen. It has, in fact, been shown that this kind of procedure is feasible, and that suitable refrigerated gas-storage conditions could be achieved in the course of the first or second day from loading (at tropical temperatures, 80–85° F), provided gas leakage was negligible. It may therefore be anticipated that the commercial gas storage of bananas will be achieved by a system of restricted ventilation in conjunction with the removal of excess carbon dioxide by chemical means. In systems of this kind, the part played by physiologically active volatile substances, such as ethylene, liberated from ripening fruit and known to accelerate ripening, may be of critical importance. In laboratory experiments, heavy three-quarters full fruit has been satisfactorily stored for twenty days at 53° F, using the method of restricted ventilation. On being removed from the containers the fruit was still quite green, subsequently ripening to a product of good colour, flavour, and aroma, whereas the control fruit underwent some ripening during cold storage and was severely chilled. But in comparable experiments where heavier grades of fruit were used, the occasional ripening fruit, by giving off ethylene, accelerated the ripening of the aggregate of fruit in the container. The next stage is to extend the experimental work to large-scale batches of fruit. In due course data will be available for the construction of ships' holds suitable for the gas storage of tropical fruits. Provided no other factors intervene, the bigger and better banana, in fact, should soon be available.

OTHER TROPICAL FRUITS

Thus far, reference has been made chiefly to the banana, by way of indicating some of the problems that arise in relation to the overseas transport of tropical fruit. We have, however, merely touched on the fringe of the subject. Each kind of fruit presents its own particular problems: variety, harvesting maturity, handling from plantation to ship, cooling, transport temperature, avoidance of chilling, ripening, and the control of wastage. Different varieties may require different storage temperatures, for example avocado and mango. The same variety grown under different environmental conditions may also require different storage temperatures, for example grapefruit. With avocados and mangoes a not inconsiderable part of the task of the refrigeration biologist has been to select from the vast assemblage of species and varieties those which possess both appearance and quality and also keeping quality in storage. Where the storage temperature is relatively high (for example 55–60° F), the control of fungal wastage presents serious difficulties, since many tropical fungi grow readily at temperatures above 55° F. In fact, a nice balance has to be struck between the danger of chilling on the one hand and the onset of fungal wastage on the other. There is also the added difficulty that, on ripening at higher temperatures, chilled fruit is more subject to fungal wastage. Limes may be cited as an example where the actual refrigeration problems are simple, the main difficulty being to prevent excessive transpiration, i.e. loss of water by evaporation.

The reader may perhaps wonder how the export of tropical fruits is likely to be affected by the increased use of air transport, with all its advantages of speed. Air transport obviously provides the ideal means of curtailing the time between harvesting and retailing, and for handling the small preliminary consignments with which new ventures must necessarily begin. It is a fact of experience that the absence of suitable refrigerated shipping, capable of carrying small experimental lots of fruit exactly as required by the scientific investigator, has been a serious handicap to the development of fruit export industries during the past twenty to thirty years. Air transport affords, as it were, the heaven-sent means of overcoming many of the difficulties that arise in connection with the export of tropical fruits. Bulky materials such as bananas or grapefruit are, of course, ruled out; but as a means of transporting sample quantities of exotic fruits in their pristine condition during the establishment of new industries, the transport aeroplane may well come to occupy an important position.

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Book reviews

A PHYSIOLOGICAL TRIBUTE

The Integrative Action of the Nervous System, *by Sir Charles Sherrington. Pp.* 433. *Cambridge University Press.* 1947. 25*s. net.*

To reprint Sir Charles Sherrington's *Integrative Action of the Nervous System* must have been a rare pleasure to the Physiological Society, for in choosing this way of marking the International Congress of Physiology, recently held at Oxford, it has not merely paid the most graceful of tributes to the book's venerable author but has honoured British physiology, the lustre of which in our day is in so large a measure the reflection of Sherrington's genius.

To those newly embarked upon the study of physiology in 1906, when 'The Integrative Action' was first published, the book was an inspiration and a stimulus that it is difficult even now to recall without again feeling the sense of excitement that rises within us at the recognition of a work of genius. Indeed, it was impossible for the critical reader not to realize that here was one of the rare records of achievement and thought in the realm of science that would in time come to take its place with Newton's *Principia* and other works of that high order, as a book that would live however far the advance of knowledge might lead us.

Here were new facts in abundance, and how beautifully co-ordinated! With what logical precision their exposition advanced from step to step, and with what penetrating scientific imagination was their significance revealed! The researches which went to the making of this book remain the foundation upon which every young neurophysiologist must still build, and the rhythm of observation and interpretation that Sherrington's work has always displayed is in the true tradition of natural philosophy.

In its new form this classic book, therefore, should invigorate the work and thought of new generations of physiologists and help to save them from the chains of an unimaginative technology which so easily weigh down the spirit of the young scientist in this age of immense technical ingenuity, when it has become difficult to contemplate the facts of observation with the leisure and calm that their philosophical synthesis demands.

F. M. R. WALSHE

NEWTON AND THE MINT

Newton at the Mint, *by Sir John Craig. Pp. viii* + 128, *with* 4 *plates. Cambridge University Press.* 1946. 7*s.* 6*d. net.*

In 1696 Montagu—later Lord Halifax—then Lord of the Treasury, wrote to Newton: 'I am very glad that at last I can give you a good proof of my friendship and the esteem the King has of your merits' and offered him the post of Warden of the Mint. Newton, who had for some time been seeking a comfortable administrative post, accepted, and after three years was raised to the chief post, that of Master. The last third of his life was thus passed at the Mint. He took his work there very seriously, and any complete survey of the life of this enigmatic man must take account of that period, which has not received much attention from his biographers.

The information which has hitherto been lacking is furnished by Sir John Craig's little book on Newton's work at the Mint, which is written with expert knowledge. It explains the peculiar constitution of the Mint at the beginning of the eighteenth century and the various responsibilities which fell to the Warden and Master. In this book we see Newton as anything but the dreamy and unworldly sage some of his admirers have depicted: he undertook with great efficiency complicated administrative problems, he laid stress on the keeping of clear records, and he seems to have been a shrewd judge of men. We may regret that such a man should have occupied himself with such things, but we must remember that it was apparently at his own wish. One *Principia* and one *Opticks* are perhaps all that we have a right to expect of one man.

E. N. DA C. ANDRADE

TEXTILE FINISHING

An Introduction to Textile Finishing, *by J. T. Marsh. Pp. xv* + 552. *Chapman and Hall Limited, London.* 1947. 35*s. net.*

In writing this book the author has undertaken, with unquestionable success, the onerous task of collecting and presenting in a systematic manner the technical and scientific aspects of an extremely wide branch of textile manufacture. The difficulty of selecting a suitable division of the many branches of the subject has largely been overcome by the judicious use of material or process as subject-matter for each chapter. Thus the main finishing processes of wool are described under permanent set, milling, and unshrinkable finish. Finishing materials, such as starch, cellulose derivatives, formaldehyde, and rubber, provide the headings of other chapters. Finishing machinery, anti-shrink methods, and the processes of crêping, softening, weighting, and delustring are adequately described. Especially useful are the theoretical and practical treatments of wool finishing and, as is to be expected, of the internal and external application of polycondensates, in which field the author has made a major contribution. The proofing of textile materials against water and attack by moth, mildew, and fire is comprehensively reviewed. References to the literature are fairly adequate but somewhat lacking in completeness of documentation. The diagrams are numerous and appropriate, although a few lack clarity (e.g. with reference to the path of the fabric under treatment) owing to over-simplification and their small size. The book is well printed and practically free from typographical errors. Mr Marsh is to be congratulated on a further valuable contribution to the literature of textile chemistry and technology.

F. O. HOWITT

CELLULOSE CHEMISTRY

The Methods of Cellulose Chemistry, including Methods for the Investigation of Substances associated with Cellulose in Plant Tissues, *by Charles Dorée. Second edition, revised and enlarged. Pp. xii* + 543. *Chapman and Hall Limited, London.* 42*s. net.*

The earlier edition of Dr Dorée's book very successfully provided a description of the important methods used in the investigation of cellulose. The author has now increased the indebtedness of all sugar chemists to him by the publication of a new edition which incorporates the advances of the past fifteen years. Extensive additions and alterations have been made, as for example in the section on oxycellulose, which now includes accounts of the oxidation of cellulose with reagents such as permanganate, periodic acid, and nitrogen dioxide. There are sections on the mixed esters of cellulose and on the various ethers, in addition to full treatment of the methods used for acetates, nitrates, xanthates, and other esters. In Part III the reader will find an up-to-date account of the methods used in

the investigation of the hemicelluloses, lignin, and pectic materials. Industrial aspects are well covered, and in addition to analytical procedures for cellulose and its derivatives, including regenerated cellulose, there are chapters devoted to the analysis of wood and wood pulp. The information given is often not readily available in the literature (to which copious references are given), and the methods are accurately described with abundant notes and illustrations. Misprints and errors are few, and the book is a pleasure to read and handle. It will be indispensable to chemists engaged in these fields of investigation. E. L. HIRST

THE PRINCIPLES OF CHEMISTRY

A Rational Approach to Chemical Principles, *by J. A. Cranston. Pp. vii + 204. Blackie and Son Limited, London.* 1947. 8*s.* 6*d. net.*

It is a pleasure to recommend this useful book because of the intelligent point of view from which it has been written. The author begins with a brief summary of atomic structures, referring to quantum levels and electronic configurations. Then follows the orthodox theory of the gaseous state, liquids and solutions, a section on valency theory and energy changes (thermochemical), one on changes involving the consideration of electrode potentials, and finally the study of chemical equilibria, including ionic dissociation.

The scheme is quite attractive and the book is well written. It contains nearly all the general and physical chemistry needed for the Higher School Certificate and university scholarship examinations. The treatment is probably not full enough for it to serve as more than a class-book, however, and there are some omissions, such as order of reaction, indicators, and the determination of hydrogen ion concentration. The aim has been simplicity and clearness, and here and there things are made to look rather easier than they should be. The treatment of electrolysis is sketchy, and the view that uncharged sulphate ions can react with water or are even discharged at all is surely now generally abandoned. The same may be said of sodium ions. In this, and the too-brief reference to the complete dissociation of strong electrolytes, the book is disappointing; in most other respects it is in refreshing contrast to many other works covering the same ground. A. E. BELL

INDUSTRIAL RESEARCH

Co-operative Research in Industry, *by D. W. Hill. Pp. 147. Hutchinson's Scientific and Technical Publications, London.* 1946. 10*s.* 6*d. net.*

The foods and materials Britain has to import now cost so much more than previously that her only chance of paying for them, argues Dr Hill, is to export brains in the form of improvements to manufactures achieved through research. Fortunately, the war showed she need not despair of doing this, for so remunerative is properly co-ordinated research that two or three fundamental inventions might well replace the whole of the capital wealth expended during those years. In that integration co-operative laboratories are a necessity, not to supersede those of individual firms concerned with competitive products but to support and stimulate them through researches on 'standard products common to the industry, the study of generally used raw materials, the improvement of standard processes and methods, the introduction of testing procedures.' The author gives an admirable account—much fuller than a mere list—of the development and organization of laboratories existing with these objects under the Department of Scientific and Industrial Research, the trade research associations which it supports, and others which are independent, including those concerned with agriculture. Later chapters describe the corresponding bodies in the overseas Empire and those, on interestingly different lines, in the United States.

Dr Hill does not, however, define research or explain to the uninitiated how it differs from other laboratory work. His statement that 'the change from the England of Queen Elizabeth to the England of today springs from the knowledge hardly wrought by research' would be truer if 'Victoria' were substituted for 'Elizabeth'; for this is to stretch the term to cover fortuitous profiting from experience as well as those purposeful programmes of research to which the quicker tempo of our own times is mainly due. Some clarification of this point would have improved a valuable book, as would greater emphasis on the importance—equal to that of the actual experimenters—of those concerned with editing, disseminating, abstracting, and indexing scientific papers, and whose function is to harmonize different lines of research. J. E. HOLMSTROM

BRITISH BIRDS

Our Bird Book, *by Sidney Rogerson and Charles Tunnicliffe. Pp. 128, with many coloured illustrations. William Collins, London.* 1946. 21*s. net.*

Mr Rogerson knows a great deal about birds, and he writes about them in a pleasantly informal manner. This is largely a book of personal reminiscence and anecdote; yet, within a small compass of words, it is astonishingly complete. The reading of it would give a child a really good introduction to a life-time's hobby, and the sort of introduction that is wanted—the introduction to the bird as an individual. Charles Tunnicliffe's drawings are true portraits of birds, delightfully crisp and full of life. It has been said with truth that Lewis Carroll's Alice cannot be fully appreciated before one is 40. Childhood has no age-limit, and this, too, is a book for children of all ages. It certainly deserves a place on the shelf of every bird-lover.

BRIAN VESEY-FITZGERALD

THE CHEMISTRY OF FATS

The Chemical Constitution of Natural Fats, *by T. P. Hilditch. Pp. xiii + 554. Chapman and Hall Limited, London. Second edition.* 1947. 45*s. net.*

It is seldom that a research worker can be in the happy position of writing, on a group of natural products of great industrial as well as academic interest, a textbook which is very largely an account of his own work. During the past thirty years no name has been more closely associated with the chemistry of fats than that of Hilditch, and when the first edition of his book appeared in 1940 it was acclaimed as a masterly interpretation of his own researches, which had for twenty years or more been centred on the structure of glycerides. The new edition contains much new material from recent publications, and opportunity has been taken to rewrite or partly to rewrite certain chapters. Besides the more amplified data now presented on the component acids and glycerides of natural fats, the author gives a full presentation of the present position with regard to the constitution of the individual fatty acids and the broad field of the biochemistry of fats. The book is the most authoritative statement of the chemistry of fats that has yet been produced, and is likely to remain so for many years to come. A. C. CHIBNALL

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Was born of Swiss stock on 21st April, 1889, in Moscow, where his parents were then living, though three years later they returned to Switzerland. There he studied at the Gymnasium at Aarau, taking his degree in 1908. Later he studied at the University of Zürich under Professor Alfred Werner, and in 1911 was awarded his Ph.D. degree for research on the nitrosopentammine-cobalt salts. From 1911 to 1912 he acted as assistant to Professor Werner, and from 1912 to 1918 was collaborating with Paul Ehrlich in the Georg Speyer Haus at Frankfurt-am-Main. Since 1919 he has been Director of the Chemical Institute of the University of Zürich. He has published numerous articles on various branches of organic chemistry, especially on vitamins, carotenoids and other plant substances, amino acids, carbohydrates, and organic compounds of arsenic. He was awarded a Nobel prize for chemistry in 1937.

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Has held the position of Astronomer Royal since the year 1933. He was born in London in 1890 and was educated at Latymer Upper School, Hammersmith, and Jesus College, Cambridge. From 1913 to 1923 he was Chief Assistant at the Royal Observatory at Greenwich, and from 1923 to 1933 held the post of His Majesty's Astronomer at the Cape of Good Hope. He was knighted in 1943, and in the same year was awarded the Royal Medal of the Royal Society and the Gold Medal of the Royal Astronomical Society. He is a past president of the latter Society and of the British Astronomical Association, and was vice-president of the International Astronomical Union from 1935 to 1938. President of the British Horological Institute, he is also a Foreign Associate of the National Academy of Sciences (U.S.A.) and an Honorary Member of many Dominion and foreign astronomical societies. He has recently been elected to membership of the *Accademia dei Lincei.*

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Was born in 1890 and was educated at London University and the Royal College of Science. He joined the Assay Department, Royal Mint, in 1912. In 1923, after returning from service with the Ministry of Munitions during the war of 1914–18, he was appointed Senior Technical Officer (Metallurgical). During the late war he was engaged by the Ministry of Supply as Assistant Controller for Non-ferrous Metals. At the end of the war he returned to the Royal Mint as Chemist and Assayer. He is a member of Council and past vice-president of the Institution of Mining and Metallurgy, and treasurer of the Institute of Metals.

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Was born at Nantwich, Cheshire, in 1888 and was educated at Bradfield College, Ellesmere College, Shropshire, and Nantwich and Acton Grammar School. He entered the Royal Navy but was disqualified by defective sight, and afterwards studied medicine and zoology at the University of Manchester. He taught zoology until the outbreak of the war of 1914–18. He then resumed medical studies and entered the Royal Army Medical Corps, serving as a pathologist in Iraq. In 1916 he returned to teach zoology at Manchester. In 1921 he organized the new Department of Zoology at University College, Exeter, where he remained until 1930. He then took up his present work on parasitology at Cambridge. His scientific publications include two books, *Parasites* (1929) and *Nematodes Parasitic in Animals* (1937), and many articles in scientific journals. He has also written much on non-scientific subjects.

C. W. WARDLAW,
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Was born in 1901 and was educated at Paisley Grammar School and Glasgow University. From 1921 to 1928 he was lecturer in botany and mycology at Glasgow. In 1928 he joined the staff of the Imperial College of Tropical Agriculture, Trinidad, British West Indies, to investigate problems relating to diseases of the banana and the transport and storage of tropical fruit. In connection with his work he travelled widely in Central and South America, and through his contacts with planters, shippers, and distributors he has become a recognized authority on these subjects. He has long held the view that tropical botany ought to be given the fullest support, not only for utilitarian reasons but for the possibilities it affords of advancing the science as a whole. Since 1940 he has been Professor of Cryptogamic Botany in the University of Manchester.

Made and printed in Great Britain at THE KYNOCH PRESS, *Witton, Birmingham, 6, for the publishers,* IMPERIAL CHEMICAL INDUSTRIES LIMITED, *London, S.W.1*